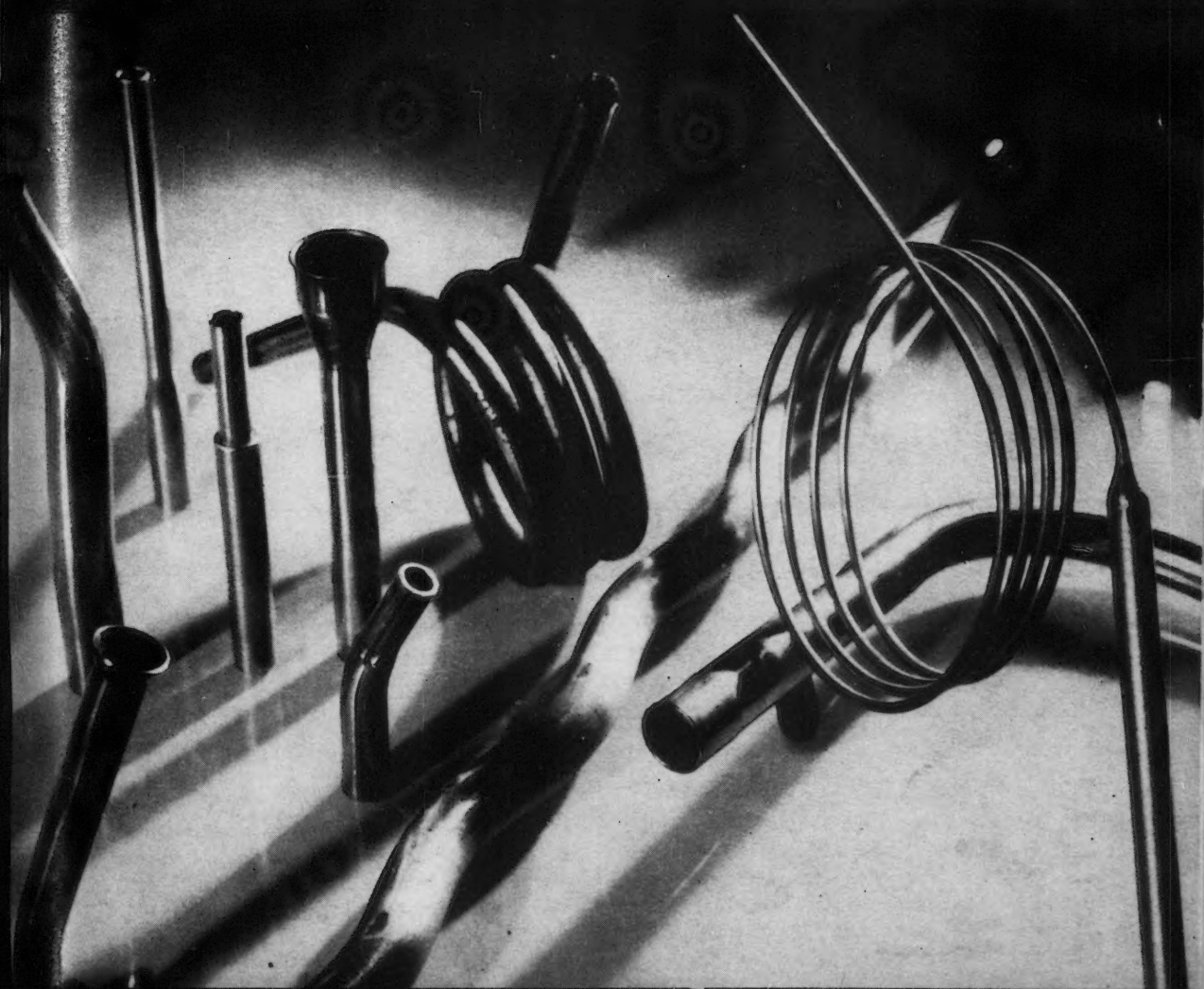
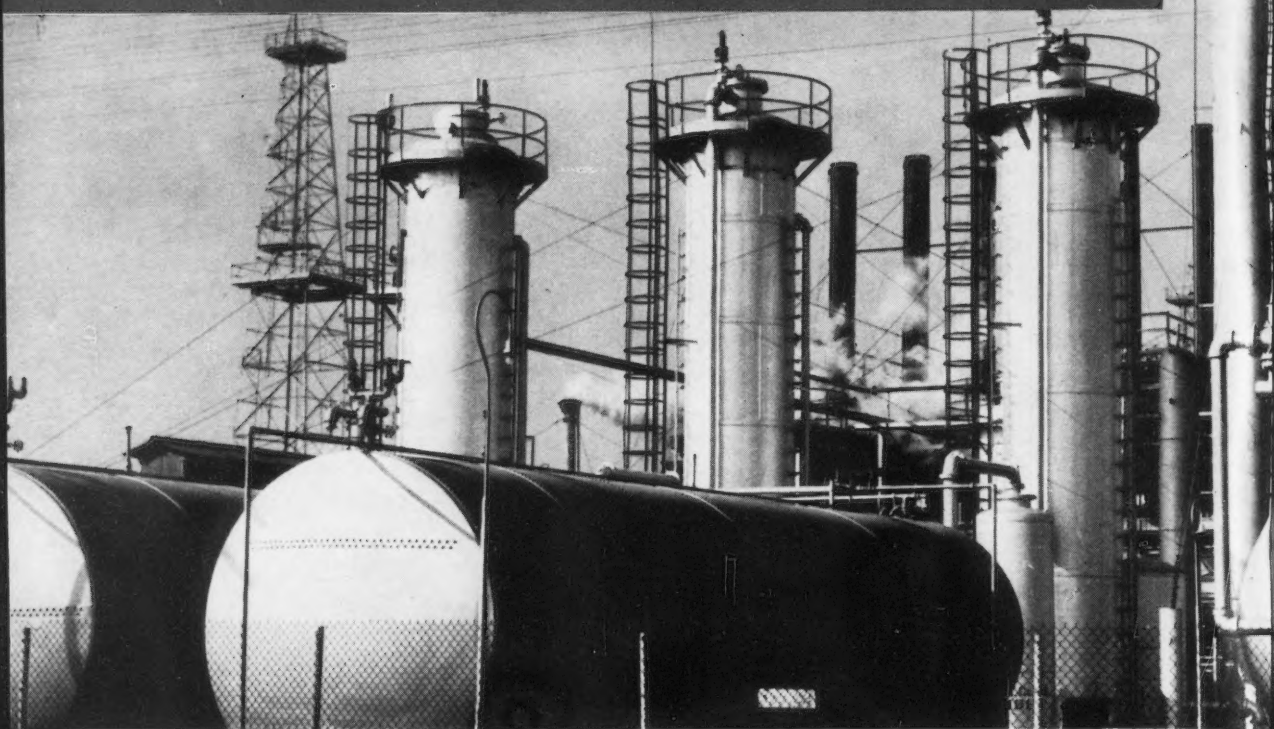


# Corrosion



JANUARY 1953

# There's more to CORROSION than meets the eye



## Sometimes VISIBLE...Often HIDDEN...Corrosion Strikes in Every Plant

This year, American Industry will pay more than \$6,000,000,000 for losses created by corrosion... *yet much of this corrosion may never be discovered* until it's too late to protect—and time to pay!

Corrosion is readily detected when it appears as rust layers or failing paint on exposed surfaces. But, by far, the major costs of corrosion come from hidden areas—where only minute inspections and constant care can prevent costly failures.

### YOU LOSE IN A "WAITING GAME"

Don't wait for rust or other visible signs to appear. Visible or hidden, corrosion will destroy costly equipment...halt production...cause unnecessary maintenance shutdowns...and contaminate valuable products. Thus, corrosion dips deep into your profits as it creates needless losses totaling thousands of dollars.

### YOU CAN PREVENT NEEDLESS WASTE

Check your plant for corrosion's presence. Double-check areas that are vulnerable to *hidden corrosion*. If you would like help, an AMERCOAT Field Engineer will gladly assist you in making a thorough analysis. There is no obligation.

**What is AMERCOAT?**  
AMERCOAT is a method of corrosion control. Not just a single product, but a complete LINE of coatings, individually formulated to solve or control specific industrial corrosion problems.

FOLLOW THE LINE OF *most* RESISTANCE... PROTECT WITH *Amercoat!*

**AMERCOAT CORPORATION**

4809 FIRESTONE BLVD., SOUTH GATE, CALIFORNIA

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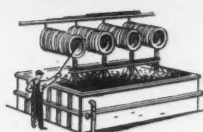
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# For PROTECTION *that fits the Job*

*Specify* **PITT CHEM**  
**TAR BASE COATINGS**

**PITT CHEM 101**



A heavy-film coating for protection of metal, masonry, stone and brick against very corrosive vapors, acid and alkali spillage and extreme moisture conditions.

**PITT CHEM 102**



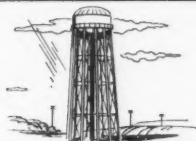
A thin, high gloss maintenance coating to protect metal and concrete surfaces against normal atmospheric corrosion, mildly corrosive vapors and moisture.

**PITT CHEM 103**



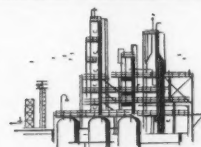
A heavy duty general maintenance coating for moderately severe corrosive conditions like dilute mineral acids, alkalis, sewage, moisture and corrosive vapors.

**PITT CHEM 104**



Specifically formulated to protect potable water tanks and water transmission equipment. Dries very quickly and imparts no taste or odor to potable water.

**PITT CHEM 105**



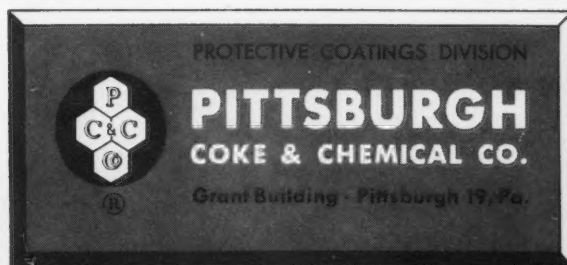
An irreversible, fast drying coal tar emulsion which provides excellent corrosion resistance on metal, concrete, brick and stone.

W&D 4430 B



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Corrosion Control  
Booklet

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## Engineered "Wool" . . . to keep a baby warm!

Lucky baby!

You can sleep like a top under your soft Dynel blanket. For it's as warm as wool, yet it has properties a sheep never dreamed of . . . and they were engineered into it by modern chemical science. Dynel is strong, flame-proof, mildew- and moth-proof. It's light, and comes from the wash as fluffy as a kitten.

Dynel, Orlon, Dacron, Acrilan, Vicara, and other man-made "wonder" fibers are made from chemical solutions. These raw solutions must be kept absolutely pure as they pass through hundreds of valves that control their flow and regulate their proportions on the way to spinnerets, where these solutions are transformed into gossamer textile fibers. To guard against any contamination or discoloration resulting from valve corrosion, the manufacturers of Dynel and other new synthetic fibers

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Like the manufacturers of engineered fabrics, other leading chemical firms, handling everything from blood plasma to oil refinery sludge, have brought their problems of corrosion, contamination, discoloration, and extreme temperatures to *Aloyco's Corrosion Engineering Service*. There, in the laboratories of the world's largest specialists in corrosion-resistant valves, the right alloy and the right type of valve have been determined for every specific corrosive situation. In fact, ALOYCO valves go hand-in-hand with chemical progress.

So if corrosives play a part in your business, write to ALOYCO about your own valve needs. Our engineers will be glad to test various alloys under your actual line conditions, and on that basis, recommend the best valve for each particular assignment.

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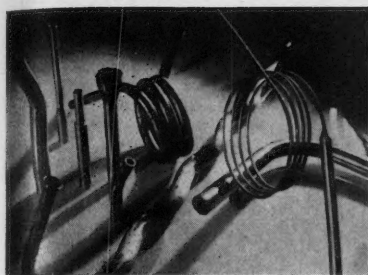
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**THIS MONTH'S COVER**—Small diameter stainless steel capillary tubing, primarily in Types 347 and 316 analyses such as these are finding important new applications in precision measuring instruments. Needle tubing is available in standard gauges from 33 gauge (.008 inches OD) to 6 gauge (0.203 inches OD) and usually is furnished in random lengths in annealed, half-hard and full hard tempers. The tubes pictured were made by Superior Tube Company, Norristown, Pa.



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devoted entirely to  
**CORROSION**  
research and control



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Vol. 9

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## MANUSCRIPTS APPROVED FOR PUBLICATION

The Coupon Technique—A Valuable Tool for Corrosion Testing by H. L. Bilhartz and H. E. Greenwell, Atlantic Refining Co., Dallas.

Effect of Heat Treatment and Related Factors on the Corrosion Resistance and Mechanical Properties of the Straight-Chromium Stainless Steels by F. K. Bloom, Armco Steel Corp., Baltimore.

Views of the Mechanism of Pitting Corrosion of Aluminum by P. M. Aziz, Aluminum Laboratories, Ltd., Kingston, Ontario.

Corrosion of Domestic Galvanized Hot Water Storage Tanks by I. L. Newell, Henry Souther Engineering Co., Hartford, Conn.

Electrochemical Behavior of Metals as a Basis for the Study of Corrosion by R. Piontelli, Politecnico di Milano.

Economic Aspects of Cathodic Protection by Ray M. Wainwright, University of Illinois, Urbana.

The Association also welcomes at any time constructive discussions of its technical material and technical papers on corrosion for publication in Corrosion.

Interested authors may secure on request a copy of the "NACE Guide for the Preparation and Presentation of Papers" which describes the Association's customs and needs more fully.

# NOW

# a new self-cleaning

**-WITH  
JET  
ACTION-**

10

**only three minutes  
to clean basket  
and get back on stream**

Here is an entirely new approach to clean pipe line products. Not only does this strainer remove the solids from the fluid, but, of even greater importance, it reduces the cleaning time to only a few minutes and thus eliminates the necessity for by-passing.

Note in the cutaway view above how banks of rotating jets (4) are arranged to clean the basket by hydraulic impact. One minute of this rotary scouring action, utilizing line product or water under high pressure, cleanses the basket and flushes the solids

down the drain (9). Only a couple of minutes more are needed to return the clean strainer to service (see below). Thus, when a pig is in the line and the strainer is needed most, the Jet Type Strainers may be cleaned so rapidly that there is never any question of by-passing. Meters are protected at all times and the product is accurately measured.

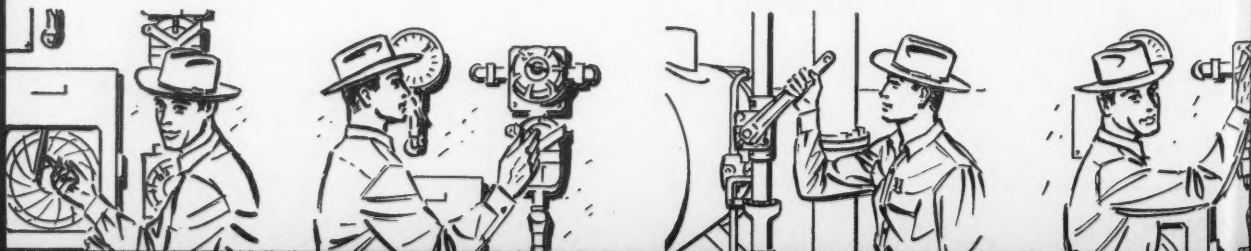
Another direct benefit is the saving in man-hours. It is not necessary to remove, clean, and replace felts as in conventional strainers.

Pressure differential recorder tells you when basket needs cleaning.

Turn selector switch to number of strainer to be cleaned.

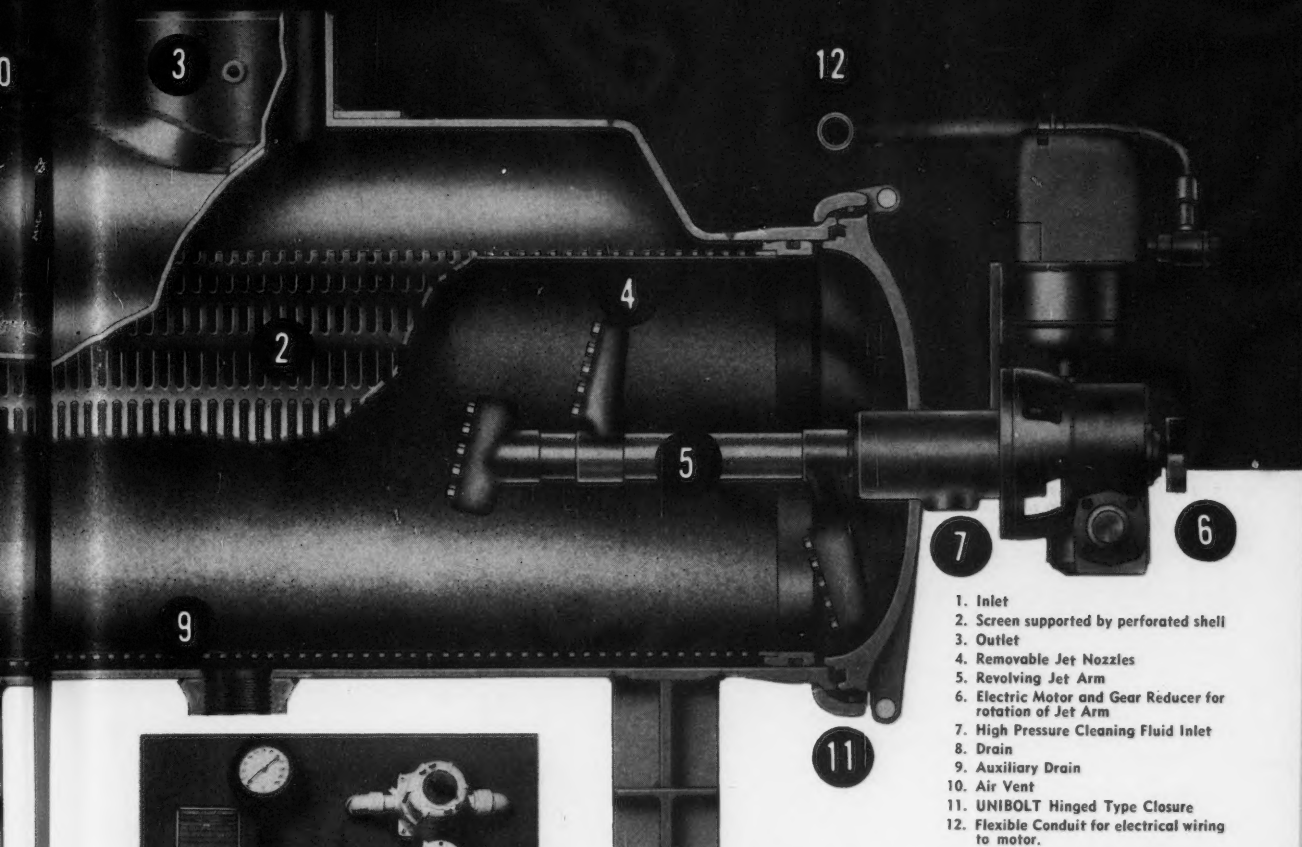
On strainer to be cleaned, close inlet and outlet and open drain, air relief, and cleaning fluid valves.

Depress starter switch for one minute.

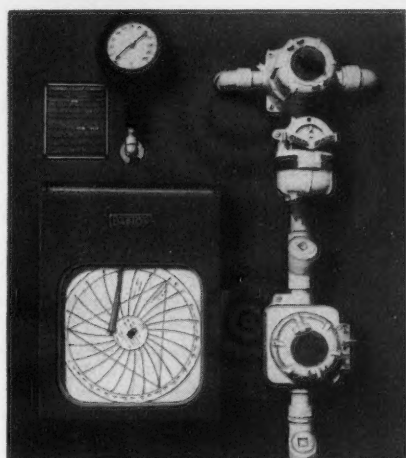




# ing pipe line strainer-

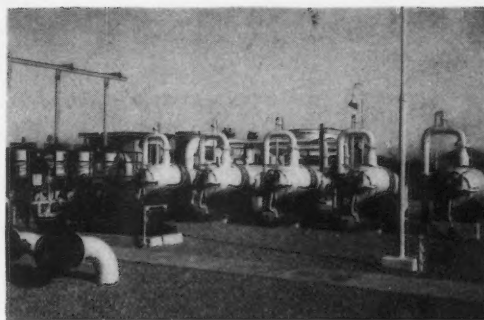


1. Inlet
2. Screen supported by perforated shell
3. Outlet
4. Removable Jet Nozzles
5. Revolving Jet Arm
6. Electric Motor and Gear Reducer for rotation of Jet Arm
7. High Pressure Cleaning Fluid Inlet
8. Drain
9. Auxiliary Drain
10. Air Vent
11. UNIBOLT Hinged Type Closure
12. Flexible Conduit for electrical wiring to motor.



← Left—Control panel consisting of pressure differential recorder, jetting pressure gauge, selector switch, and starter switch.

→ Right — Five, 30,000 bbl. capacity, Jet Type Strainers installed on a 14-inch products line in North Carolina.



The Jet Type Strainer need never be opened except to inspect or to exchange the basket. A hinged UNIBOLT Closure of the type now in wide usage on scraper traps provides easy access to the unit by simply releasing two bolts. The basket consists of a perforated monel metal shell with stainless wire screen

of any desired size — 100, 200, 325, or 400-mesh.

Another unique feature is the Pressure Differential Recorder (see illustration above) which records the pressure differential between the inlet and outlet sides of the strainer. When this pressure reaches a predetermined value, the basket should be cleaned.

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(Continued from Page viii)

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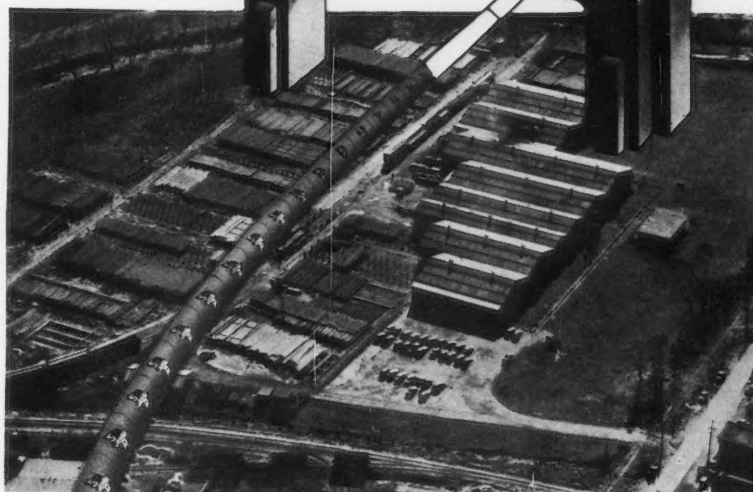
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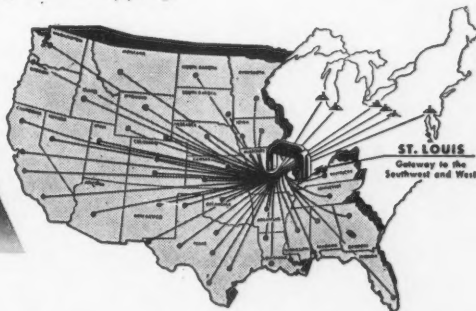
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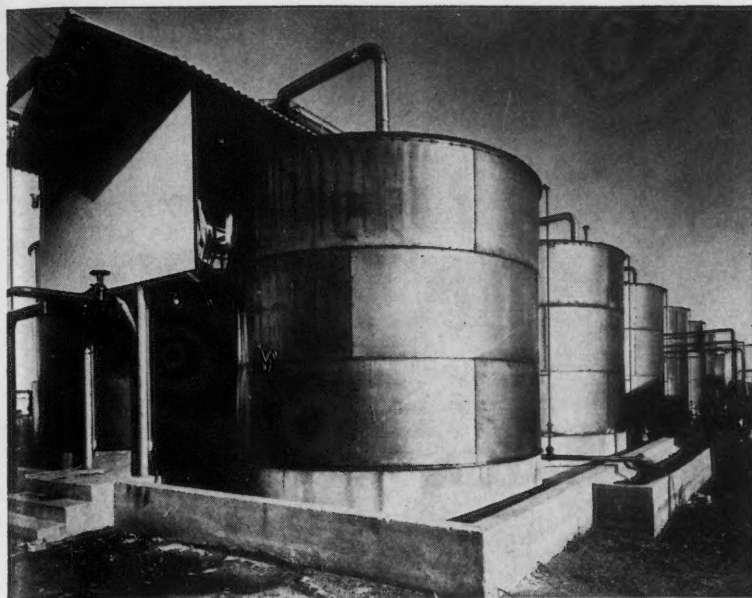


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Some of the 24 Monel Twitchell splitting vessels installed by the Southern Cotton Oil Company. These tanks have been in service four years and have required minimum maintenance. Approximately 120,000 pounds of 0.125" sheet Monel was used to fabricate the self-supporting fat-splitting tanks.

**These fat-splitting tanks**

## **ended leakage—ended caulking**

**... for Southern Cotton Oil Company**

After four years, the Southern Cotton Oil Company is still getting excellent service from those tanks—but that's just what you would expect of Monel®!

The Twitchell splitting vessels they had used previous to Monel had often required attention involving caulking of riveted joints and repairing at the seams to prevent leakage.

With the welded Monel tanks they have had none of this expensive and time-consuming maintenance.

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Prominent manufacturers of stearic acid, red oil, glycerine and allied chemicals report service records up to eleven years for Monel tanks and heating coils.

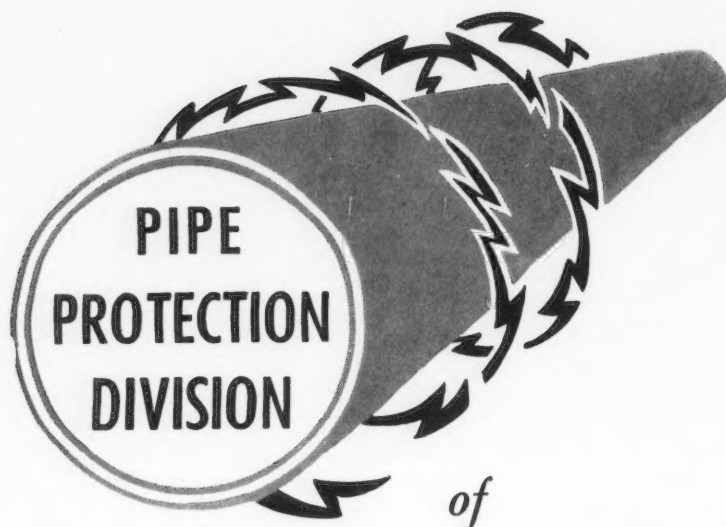
Consult your Distributor of Inco Nickel Alloys for the latest information on their availability from warehouse and mill. Remember, too—it always helps to anticipate your requirements well in advance.

And for help with problems connected with the manufacture and handling of fatty acids, remember you can always count on Inco's Technical Service and Corrosion Engineering Section. Write them today. The International Nickel Company, Inc., 67 Wall Street, New York 5, N. Y.

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Today's shortage of metals has made replacement of equipment a serious problem. Many companies are, therefore, putting greater emphasis on preventive maintenance than ever before. They have found that using chemical resisting Ucilon Protective Coatings on a regular basis avoids corrosion damage to equipment and thereby minimizes not only the need for replacement but also the costly downtime.

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Such systems are available to deal with a "hundred and one" tough, corrosive conditions. These include intermittent or continuous contact with fumes or solutions—with acids, alkalies, salts, alcohols, moisture, oils, greases, foods, chemical compounds and other products. Some systems require baking. Most, however, dry by solvent evaporation; still others by oxidation. All are easily applied by brushing or spraying.

#### WHAT USERS SAY ABOUT IT

"We have yet to have a failure of any con-

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Today is no time to put up with needless corrosion of equipment, with resultant production delays, with the downtime and expense of "painting" required too frequently. You can do successful preventive maintenance as it is being done in other processing plants—where Ucilon Coating Systems, applied to equipment and plant, are giving longer lasting protection at lower cost.

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is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

- (a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.
- (b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.
- (c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.
- (d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.
- (e) To promote standardization of terminology, techniques, equipment and design in corrosion control.
- (f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.
- (g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.
- (h) To invite a wide diversity of membership, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers and elected directors are nominated by a nominating committee in accordance with the articles of organization. Election is by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 1061 M & M Building, No. 1 Main Street, Houston 2, Texas.



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FRANK L. WHITNEY, JR..(North Central) 1950-53  
Monsanto Chemical Co., St. Louis, Mo.

E. D. McCAULEY.....(South East) 1952-54  
American Cast Iron Pipe Co., Birmingham, Ala.

T. F. P. KELLY.....(South Central) 1950-53  
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Board of Harbor Commissioners, Long Beach, California.

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## Technical Practices Committee 5

## Corrosion Problems Involved in the Processing and Handling of Chemicals

By H. W. SCHMIDT, Chairman\*

THE POTENTIAL field of activity for this committee is obviously very extensive since it is concerned with chemical and process industries. While a wealth of information on the corrosion resistance of materials of construction exists in the various handbooks and in the publications of numerous technical societies many of the published data are of questionable value for use in the design of equipment because they deal to a large extent with relatively pure chemicals. It was felt that a need exists to augment and clarify the existing data by accumulating information not previously published.

The organization of Technical Practices Committee 5 was undertaken in 1948 under the able leadership of Dr. Mars G. Fontana. The committee was charged with several responsibilities:

- 1) to determine the materials of construction suitable for use in handling and manufacturing various chemicals;
- 2) to obtain all available information from industry on the corrosion resistance of materials;
- 3) to initiate tests where indicated;
- 4) to ultimately prepare codes designating the most suitable materials and methods of construction for various types of chemical equipment for use in corrosive service.

Originally, five subcommittees were formed as follows:

- 5A—Materials for Handling and Manufacturing Sulfuric Acid
- 5B—Design of Equipment for Corrosive Service
- 5C—Sub-Surface Corrosion by Alkaline Solutions
- 5D—Corrosion by Organic Acids and Bases
- 5E—Gasket Materials for Corrosive Service

Questionnaires were prepared by the several committees and submitted to industries which would be interested. In general, the response to the questionnaires was not particularly good. This may have been due to the complexity of the questionnaires as well as the apathy with which questionnaires in general are received.

In spite of the difficulties encountered, two subcommittees prepared reports of their progress for the 1951 NACE Conference in New York and subsequently published in CORROSION.

Materials for Handling Sulfuric Acid by TP-5A  
Stress Corrosion Cracking by Alkaline Solutions by TP-5C

Several of the committees found it difficult to obtain information and have not been very effective. This may have been due to the very wide scope of some of the committees and was particularly true of TP-5B on Design.

At the last meeting in March during the 1952 NACE Conference, it was decided to limit the subcommittee activities to some narrow and specific objective. The subcommittees have now been reorganized on the basis of a specific corrosive. Information will be accumulated by studying one industry at a time and it is anticipated this approach will be more fruitful. Cooperative tests will be instigated in cases where data are not complete and it is expected codes will be prepared when warranted.

If the committee is to be successful in its goal, close cooperation with management of the numerous industries concerned is essential. Much can be gained by a cooperative exchange of information and experiences with materials of construction and their behavior in corrosives.

All active committee work is accomplished in five active subcommittees. While these work groups should be kept small in size for effective functioning, anyone with an active interest in the work of any subcommittee is welcome to participate and contact the chairman of the group in which he is interested.

The committee is composed of 44 members. These are about equally divided between materials and equipment suppliers and chemical manufacturing companies.

The work of TP-5 can be of immeasurable value to industry. Accomplishments can be made only by the effective cooperation of many. A welcome is extended to anyone interested in materials of construction for use in any corrosive environment to join in the work of the committee.

\* Materials Engineering Service, The Dow Chemical Company, Midland, Mich.



## A Preliminary Study

# Behavior of Shipbottom Paints Subjected to Cathodic Protection\*

By R. P. DEVOLUY

### Introduction

THE PHENOMENA of inactivation of anti-fouling paints is well known and has been the subject of study by many investigators. The Woods Hole Oceanographic Institution has written<sup>1</sup> an excellent analysis of the literature on this subject and also on its work in this field. A common example of inactivation is the interaction of zinc plates with a bronze anti-fouling paint on a wooden boat. Such paints have metallic copper for the toxic pigment and almost invariably there is intense fouling for a radius of several feet around the zinc plate. This fouling is caused by suppression of the release of the metallic copper in the anti-fouling paint by the current from the zinc. There is considerable evidence<sup>2</sup> to show that the anti-fouling paint becomes a conductor and hence acts as a cathode to form a galvanic couple with the zinc. A piece of iron will react the same as zinc.

Woods Hole investigators found that the amount of inactivation increases with the amount of metallic copper in the paint but that a minimum amount is necessary depending on the type of vehicle used. Their experiments failed to show inactivation by any cuprous oxide anti-fouling paint in contact with zinc or iron strips but they concede that this type of paint could be inactivated on a large steel surface.

Inactivation of anti-fouling paints is more common on metal boats and ships and usually comes about because of inadequate undercoats. Metallic copper anti-fouling paints are not commonly used for metal boats because of the possibility of a gross cathode effect. Cuprous oxide anti-fouling paints have been inactivated on steel vessels where insufficient anti-corrosive paint was applied under them and this was usually accompanied by pitting of the steel hull. The mechanism has not been established but seems to be caused by the plating out of copper beneath the paint film.<sup>2,3</sup> The writer has seen a destroyer escort whose pitted bottom had extensive copper deposition after six months of service where Navy Cold Plastic Anti-fouling was applied by error over a single coat of anti-corrosive paint.

Woolsey Paint and Color Company has conducted extensive test programs on this subject and it has found poor correlation between the cuprous oxide content of the anti-fouling paint and the degree of pitting on bare metal with which the anti-fouling paint was intentionally in contact. In these tests, the better binders caused the least corrosion, probably because there was little dissolution of cuprous oxide in the



R. P. DEVOLUY—Technical director of C. A. Woolsey Paint & Color Company, Inc., New York City. He first became interested in corrosion while studying engineering at City College of New York where he wrote a thesis on graphitic corrosion as his MS thesis in 1936. While serving as Assistant Laboratory Officer, Material Laboratory, New York Naval Shipyard during 1941-45 he was actively engaged in corrosion work. He is chairman of NACE Technical Practices Committee 6 C on Protective Coatings for Resistance to Marine Corrosion.

### Abstract

This paper discusses the results of a test program designed at a meeting of interested parties\* held at the Sea Horse Institute,\*\* Harbor Island, N. C. on June 8, 1950. The principal object of the investigation was to determine whether cathodic protection can be applied to operating ships without inactivating anti-fouling paints in the manner frequently observed when certain anti-fouling paints are associated with areas of bare steel or zinc. Secondary objectives concerned the effects of variations in the composition of the paints used and in variations in the dried film thicknesses of the anti-corrosive paints used in the paint systems.

Several variations of two basically different types of ship bottom paint systems were studied for inactivation of the anti-fouling point by cathodic protection. In general, it was found that ship bottom paint systems which can be expected to inactivate, and hence foul without cathodic protection, are the same paints that will be inactivated in a relatively short time by protective currents. The importance of the anti-corrosive undercoats in preventing inactivation is stressed for it was found that both cases of inactivation observed in this test were substantially eliminated by a better "barrier" coating between the anti-fouling paint and the steel plate. Paints of low permeability and good alkali resistance materially reduced the current requirements for protection.

The most important observation made in this test program was that the current density should be controlled by limiting the potential to the minimum necessary for the protection of the steel. This was not done in this preliminary investigation and hence almost all the coatings were severely damaged by the effects of the unnecessarily high currents.

\* Chairman, Frank LaQue, International Nickel Company; T. P. May, International Nickel Company; Hilary Humble, Dow Chemical Company; George Diehlman, National Lead Company; Charles Jackson; Devoe & Reynolds; S. C. Frye, Bethlehem Steel Company; R. P. Devoluy, C. A. Woolsey Paint & Color Co., Inc.

\*\* Name applied informally to the International Nickel Co., Inc., Marine Test Stations at Harbor Island and Kure Beach, N. C.

deeper layers of the paint. This mechanism has been proposed as a reason for Navy Hot Plastic rarely showing inactivation and the accompanying pitting of steel.

The remedy for inactivation on steel vessels is simply to apply an adequate thickness of anti-

\*A paper presented at the Eighth Annual Conference, National Association of Corrosion Engineers, Galveston, Texas, March 10-14, 1952.

corrosive paint between the anti-fouling paint and the steel hull. One ship on which the writer found inactivation and accelerated pitting was cured of this difficulty simply by sand-blasting off the entire paint system and then applying three coats of anti-corrosive paint and one coat of the same anti-fouling paint (Navy Cold Plastic) that had caused the original difficulty. On inspection of this vessel nine months later it was found that both the inactivation and the pitting had been completely stopped.

With this background, it was natural when cathodic protection of active vessels was being considered, that the possible inactivation of anti-fouling paint by cathodic currents should cause concern and as a consequence serve as the prime objective of this study. Ship owners cannot afford to operate fouled ships and there is little evidence to suggest that cathodic deposits have satisfactory anti-fouling resistance.

### Selection of Paints

Fortunately, previous work<sup>4, 5</sup> on the effect of cathodic protection on coatings had shown that paints lacking alkali and electrical resistance were subject to some deterioration. It therefore seemed advisable to select two fundamentally different vehicle types of paint systems. The first type was the Maritime Commission specification shipbottom paints based on coal tar-resin vehicles. These are examples of the best in conventional formulations such as are widely used by ship owners today. The second group of shipbottom paints was based on vinyl resins and these had previously shown good resistance to degradation by cathodic protection currents. These paints had also proved their merit for shipbottom protection and have since been made into United States Navy and United States Coast Guard specification coatings.

After deciding on the two types of paints according to composition of the vehicle, the advisory group decided to also include a study of the following variables which could effect performance:

1. **Pigmentation of the anti-fouling paint based on coal tar-resin vehicle.** The three pigmentations tried were metallic copper, cuprous oxide with mercuric oxide and without mercuric oxide. Only the cuprous oxide pigmentation was tried for the

vinyl anti-fouling paint because that is the only one on which there is a good background.

2. **Thickness of the anti-corrosive.** A poor and an adequate film thickness were tried for both the coal tar—resin and the vinyl anti-corrosive under all of the anti-fouling paint variations.
3. **With and without scribe mark.** Prompted by previous investigations which indicated a bare metal area may help start inactivation.
4. **Varied pigmentation of the anti-corrosive paints used in the vinyl systems.** Basic zinc chromate and red lead were separately used as the pigment phase of the vinyl paints.
5. A supposedly poor pigmentation for the vinyl anti-corrosive was included and at a reduced dried film thickness.
6. Cuprous oxide anti-fouling paint was used directly on bare metal to check inactivation with and without cathodic protection.
7. Painted controls without cathodic protection, on all systems to check "normal" inactivation.
8. Bare steel panels, with and without cathodic protection, to act as controls for current requirements, potential data and for corrosion.

All paint systems were tested on duplicate panels and the bare steel control panels were also exposed in duplicate. The paints selected to evaluate these variables are described in Table I.

### Painting of Panels

Eighty-four hot rolled mild steel pieces 12 inches x 12 inches x  $\frac{1}{8}$  inch from one lot were descaled by pickling. Half of these panels had 3/16-inch diameter steel rods 24 inches long welded to the center of one edge, prior to coating, for use in coupling the anodes.

All panels were weighed and then sprayed in accordance with the paint systems listed in Table I. The edges of the panels were sprayed with the proper number of coats but otherwise received no special treatment. They were not filed down.

Film thickness of anti-corrosive and total film thickness after applying anti-fouling were carefully measured and averages for each system listed in the tables. Scribe marks 3/32-inch wide were cut through the complete coating system, across one diagonal, one side, on half of the panels in each paint system. Each paint system is therefore represented by eight

TABLE I—The Paint Systems

Paint System Number	Anti-Corrosive Specification and No. of Coats	Anti-Fouling Specification (All One Coat)	Thickness of Anti-Corrosive (Mils)	Total Film Thickness (Mils)
1	One Coat 52MC401 Type I—Brown Shipbottom Anti-Corrosive	One Coat 52MC403 A—Shipbottom Anti-Fouling (Without Mercuric Oxide)	1.5	2.5
2	Two Coats—Same Anti-Corrosive as System No. 1	One Coat Same Anti-Fouling as System No. 1	3.2	4.2
3	One Coat BU Ships Formula 117 Wash Primer—One Coat BU Ships Formula 119 Except Iron Oxide Substituted for Red Lead on a Pigment Volume Basis	One Coat BU Ships Formula 121—Vinyl Anti-Fouling (Cuprous Oxide)	3.0	5.2
4	One Coat Formula 117 Wash Primer, Three Coats BU Ships Formula 119—Vinyl Red Lead Primer	One Coat Formula 121—Vinyl Anti-Fouling (Cuprous Oxide)	6.5	8.3
5	One Coat Formula 117 Wash Primer, Three Coats BU Ships Formula 120 Vinyl Zinc Chromate Primer	One Coat Formula 121—Vinyl Anti-Fouling (Cuprous Oxide)	6.8	8.0
6	One Coat Same Anti-Corrosive as System No. 1	One Coat 52MC403A with Metallic Copper Substituted for Cuprous Oxide on a Copper Content Basis	1.4	2.7
7	Two Coats—Same Anti-Corrosive as System No. 1	One Coat same Anti-Fouling as System No. 6	3.3	4.9
8	One Coat Same Anti-Corrosive as System No. 1	One Coat 52MC403A—Shipbottom Anti-Fouling	1.5	2.7
9	Two Coats Same Anti-Corrosive as System No. 1	One Coat Same Anti-Fouling as System No. 8	2.7	3.9
10	No Anti-Corrosive	One Coat Same Anti-Fouling as System No. 1	.....	1.4
11	No Anti-Corrosive	One Coat Same Anti-Fouling as System No. 3	.....	2.8
12	Bare Steel	Bare Steel	.....	.....

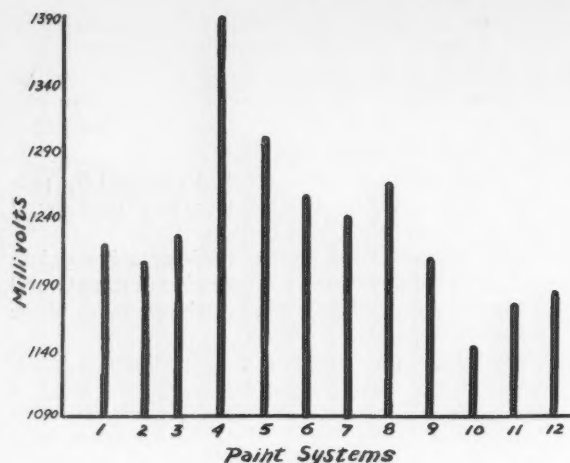


Figure 1—Potentials on 45th day.

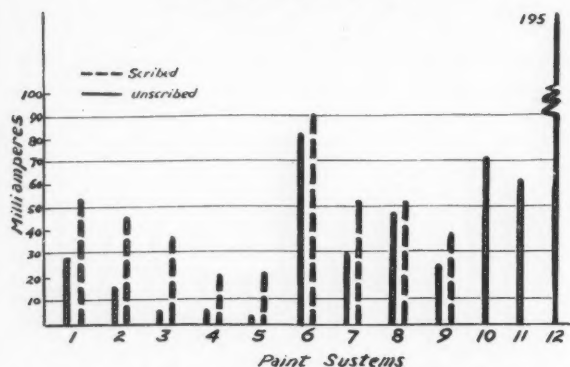


Figure 2—Initial current demands for various paint systems.

panels; four without cathodic protection, of which two are scribed and two are not, and four with cathodic protection, again two scribed and two unscribed. The panels with anti-fouling paint directly on bare metal were not scribed.

The specimens under cathodic protection were immersed in sea water for 45 days whereas the controls were immersed for eight months.

The test site was the Sea Horse Institute, Harbor Island, North Carolina. The panels were continuously submerged on racks suspended from a float to maintain a constant depth of immersion.

#### Source of Current

Current was furnished by two magnesium anodes for each panel. Each anode was a 3-inch piece of Galvoline located one foot each side of the panel. Current was controlled only by having the Galvoline coated with vinyl paint so that only ends were bare. (This worked.) Potential was not controlled.

Each panel under cathodic protection had its anodes connected through a cut-out switch by means of which the current was diverted through a 0.1 ohm shunt so that periodic measurements of potential across the shunt, and hence the current, could be determined.

Potential measurements were made with zinc as reference electrode and in Figure 1 they have been converted to the saturated calomel scale.

## Results

### Potentials

Potentials of painted specimens were taken on the 45th day of immersion, at which time the cathodic protection half of the test was terminated. Average potentials for each system are shown in Figure 1. From these comparatively high values, it is obvious why none of the specimens under cathodic protection suffered any corrosion.

Potentials for Systems 4 and 5, vinyls at proper film thickness, are higher than for the coal tar-resin paints. It is surprising that these vinyl paints were able to withstand potentials as high as 1400 millivolts with very little gas blistering and that mostly confined to the edges of the panels.

Bare plates and those with anti-fouling directly on the steel are at an appreciably lower potential than those with the coal tar-resin paints. It seems therefore, that the resistance of the paint coatings was a factor in determining the potential at which the specimen became polarized under the uncontrolled potential and current density conditions of these tests. In the case of the better coatings, current is directed to small bare spots where the high density developed soon polarizes the areas.

### Current Requirements

Nine readings were taken of the current demand for each panel under cathodic protection. The first reading was taken one hour after immersion, the next seven at two or three days intervals and the last one on the 34th day. With the exception of vinyl paint systems Numbers 4, 5 and 3 unscribed, there is very poor agreement between duplicate panels on the matter of current requirements at readings taken after the first two days. This is not surprising because the paints in most of the other systems were literally blasted off the metal. The thin vinyl system No. 3 and the vinyl anti-fouling on bare metal blistered considerably but the blisters did not break. The variation between duplicate specimens painted with various coal tar-resin paint systems shows that the usual current-versus-time curves would have little significance except to indicate which of two opposing forces was in control at the time the readings were taken. One force was that blasting off the paint and hence exposing more bare metal and the other force was that polarizing the bare areas by building cathodic deposits. Last readings of current are inconsistent between duplicate panels for the same reason; again excepting systems No. 4 and No. 5.

On the subject of impermeability, which is judged to be a most important characteristic of a shipbottom paint, Figure 2 shows significant differences between the initial current requirements of the various paint systems, scribed and unscribed. It is most interesting to find that initial current requirement is selective in dividing the paint systems into three groups and that these groups check very nicely with the protection that experience, and the control panels, have shown to be expected from the various paint systems.



**Group I**—Includes the bare panels (system No. 12), the anti-fouling paints on bare metal (systems No. 10 and 11) and the metallic copper anti-fouling over one coat of anti-corrosive (system No. 6). This group would be expected to undergo rapid corrosion and it is found that the initial current required is high.

**Group II**—Includes the coal tar-resin cuprous oxide anti-fouling over one coat of anti-corrosive (systems No. 1 and 8), the same anti-fouling paints with two coats of anti-corrosive (systems No. 2 and 9) and the metallic copper anti-fouling over two coats of anti-corrosive (system No. 7). This group should afford moderate protection and it was found that the initial current requirements are much less than those in Group I. As expected, it is possible to sub-divide this group further, for the two coat anti-corrosive systems show lower current requirements than the corresponding paint systems with one coat of anti-corrosive; compare system No. 2 versus No. 1 and No. 8 versus No. 9. Note particularly the difference one coat of anti-corrosive makes between systems No. 6 and 7 and between systems No. 10 and 11.

**Group III**—Includes the two—5-coat vinyl systems No. 4 and 5, from which good protection is expected and surprisingly, the 3-coat vinyl system with the iron oxide anti-corrosive which was expected to give only fair protection. The film thickness of this three coat system was greater than those of the three coat coal tar-resin systems. A comparison of system No. 11 (vinyl anti-fouling on bare steel) with system No. 3 demonstrates the value of one good coat of anti-corrosive.

#### Current Density

Naturally in all this discussion unscribed panels have been compared with unscribed panels. The same grouping of paint systems holds for the scribed panels but there is a difference in initial current requirements between scribed and unscribed panels of the same paint system. These differences might be expected to be the same for all paint systems since presumably they represent the extra current required to protect the scribe mark. Unfortunately, they varied considerably and hence for the calculation of initial current density it seems advisable to consider only the two high resistance vinyl paint systems. Based on a scribe area of 0.03 square foot, it develops that current densities of 500 to 600 milliamperes per square foot were applied.

With such current densities available, it is easy to see why most of the paints were soon blasted off the panels or severely blistered. There is an interesting difference in the behavior between the high resistance paints in Group III and the paint systems in the other two groups. In the latter, the paints were blasted off and cathodic deposits formed on the bare metal. The vinyls, which compose Group III, formed gas blisters which did not break and apparently stayed dry. Systems No. 3 and 5 had cathodic deposits on top of the paint blisters only. System No. 4 had not formed cathodic deposits over

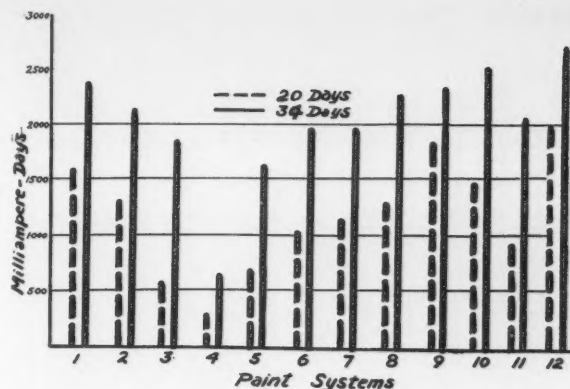


Figure 3—Cumulative current-time demands.

the dry blisters, indicating that the blisters developed late in the test or that the red lead vinyl anti-corrosive had lower permeability and would not allow the deposits to form even on top of the paint. With these vinyl paints, the metal under the blisters was clean and in some blisters it seemed that the red lead anti-corrosive had been lifted off the washcoat primer.

#### Cumulative Current—Time Data

Although the current-versus-time data is erratic at any given reading for the reasons mentioned previously, the cumulative milliamperes-days data for unscribed panels, Figure 3, does give some useful economic information. The twenty day totals are also shown (with dotted lines) because there was a fourteen day lapse between the last two readings. The thirty-four day totals are therefore subject to some inaccuracy. It is nevertheless apparent that a paint system such as No. 4 with 650 milliamperes-day total will present a saving of anodic material or other source of cathodic current, as compared to 2800 milliamperes-days required by the bare metal or the 2350 milliamperes-days required by an inadequate paint system such as No. 1.

The three groups of paints previously identified by initial current demands are also segregated by cumulative current-time requirements. The same three vinyl paint systems that composed Group III are found to have the lowest total current needs although there is considerable difference among systems No. 4, three coat red lead anti-corrosive and system No. 3 and No. 5, one coat iron oxide anti-corrosive and three coat zinc chromate anti-corrosive, respectively.

At the other end of the scale is found the bare metal and system No. 10, coal tar-resin anti-fouling on bare metal panels. Two systems No. 11 (vinyl anti-fouling on bare metal) and No. 6, which are under Group I for high initial current requirements, are now submerged in group II with the moderate protection systems.

#### Inactivation

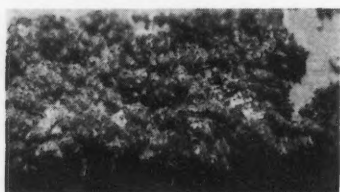
Due to the high potentials and current densities experienced and their detrimental effect on the paint



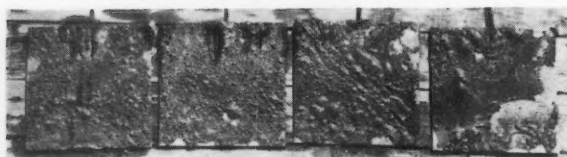
With cathodic protection—45 days



Without cathodic protection—8 months  
Figure 4—Paint system No. 6.



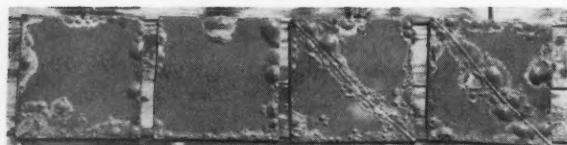
Without cathodic protection—8 months  
Figure 5—Paint system No. 10.



With cathodic protection—45 days



Without cathodic protection—8 months  
Figure 6—Paint system No. 2.



With cathodic protection—45 days



Without cathodic protection—8 months  
Figure 7—Paint system No. 3.

coatings generally the information on inactivation is limited. Briefly, the paint systems that become inactivated without cathodic protection were the same ones to be inactivated and fouled under cathodic protection. These were systems No. 6, metallic copper-coal tar-resin anti-fouling over one coat of anti-corrosive (See Figure 4) and No. 10, cuprous oxide-coal tar-resin anti-fouling over bare steel (See Figure No. 5).

Organisms on the cathodic protection panels have not grown enough to show up well in the photographs because these panels were exposed but forty-five days. The fouling on systems No. 6 and 10, without cathodic protection, did not start until several months after immersion. It is surprising that system No. 11, vinyl anti-fouling on bare metal, was not inactivated. This checks the Woods Hole theory that in thicker cuprous oxide anti-fouling paints made with less permeable binders, the lower layers of the paint are inactive.

In the case of the paints that did not show inactivation, but which were partly blasted from the steel, it is not certain results would not be different if the experiments had been conducted for a long time at lower current densities and potentials. It can be speculated that the disruptive action taking place between the paint film and the metal disturbed the process by which inactivation takes place and also prevented the gross cathode effects that usually accompany inactivation.

The fact that the controls in these paint systems did not inactivate during nine months' exposure makes this occurrence unlikely but it should be checked at lower current densities.

Results of the electrical violence are apparent in Figure 6. This shows system No. 2 with and without cathodic protection and represents what happened to systems No. 1, 2, 6, 7, 8, 9 and 10, i.e., all the coal tar-resin paints.

By comparison, see Figure 7, where the one coat anti-corrosive vinyl system, No. 3, looks good. The blistering is mostly along the edges and adjacent to the scribe marks. The blisters are dry and unbroken which probably accounts for the low cumulative current requirements of this system.

Figures 8 and 9 show the good resistance to high potential and high current density afforded by system No. 4 and 5, respectively. The edge blistering is about the same for both systems and the blisters are dry.

The bare steel controls, with and without cathodic protection, are shown in Figure 10 to indicate the intensity of fouling at this test site. The lesser amount of fouling on the cathodically protected panels is simply due to their being immersed approximately one month while the controls were in for eight months.

#### Performance of Paint Systems Without Cathodic Protection—8 Month Immersion

An analysis of the all around protection provided by the paints in the controls shows that they can be catalogued into three groups; bad, moderate and

good. The rating system used to arrive at this classification is as follows:

**TABLE II**  
Rating System for Painted Controls

	Maximum Rating
Resistance to pitting or accelerated corrosion .....	4 points
Resistance to paint film breakdown:	
(a) Blistering .....	1 point
(b) Peeling .....	2 points
(c) Cracking .....	1 point
Resistance to general corrosion.....	2 points

A perfect paint system would have a total of .....10 points

This arbitrary rating system is designed primarily from the ship owner's standpoint and applies to bottom paints only. Actually in rating a ship, rather than a test panel, one point would be assigned to abrasion resistance of the coating and the peeling resistance reduced to one point.

Paint systems on panels without cathodic protection rated using this system and then classified into three groups are shown in Table III.

Importance of the anti-corrosive is again demonstrated. Coal tar-resin systems No. 10 and 6 improve from Group I to Group II by adding one coat of anti-corrosive. For the period of this test there is not too much difference among the 3-coat vinyl system, No. 3, and the 5-coat vinyl systems No. 4 and 5, because the film thickness of a 3-coat system is over the minimum thickness required for good protection. Under drydock conditions, it would take four to five coats to obtain the film thickness of system No. 3 and at least six coats to obtain the film thicknesses of systems No. 4 and No. 5.

#### Correlation Among Properties Exhibited by the Various Paint Systems

With a few minor variations, there is good agreement among the group classifications for the paint systems as to the following properties:

- A. Initial current requirements under cathodic protection .....Figure 2
- B. Cumulative current-time requirements .....Figure 3

**TABLE III**  
Ratings of Paint Systems Without Cathodic Protection

System Number	PAINT SYSTEM	Rating
<b>Group I—Bad Protection</b>		
No. 12	Bare Steel.....	3
No. 10	Cuprous Oxide—Coat Tar—Resin A F Directly on Steel.....	2
No. 6	Metallic Copper—Coal Tar—Resin A F Over 1 Coat Coal Tar—Resin A C.....	0
<b>Group II—Moderate Protection</b>		
No. 1	Cuprous Oxide—Coat Tar—Resin A F (Without Mercuric Oxide) Over 1 Coat Coal Tar—Resin A C.....	6
No. 2	Same as No. 1 Except 2 Coats A C.....	8
No. 7	Same as No. 6 Except 2 Coats A C.....	5
No. 8	Cuprous Oxide—Coal Tar—Resin A F Over 1 Coat Coal Tar—Resin A C.....	5
No. 9	Same as No. 8 Except 2 Coats A C.....	7
No. 11	Vinyl Anti-Fouling Directly on Steel.....	7
<b>Group III—Good Protection</b>		
No. 4	5 Coat Vinyl Red Lead A C and A F System.....	9+
No. 5	5 Coat Vinyl Zinc Chromate A C and A F System.....	9+
No. 3	3 Coat Vinyl Iron Oxide A C and A F System.....	9



With cathodic protection—45 days



Without cathodic protection—8 months

Figure 8—Paint system No. 4.

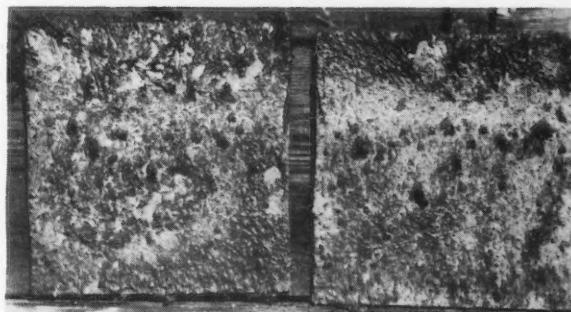


With cathodic protection—45 days



Without cathodic protection—8 months

Figure 9—Paint system No. 5.



With cathodic protection—45 days



Without cathodic protection—8 months

Figure 10—Paint system No. 12.

- C. General protection offered by paint systems to panels without cathodic protection .....Table III

It is possible this agreement between current requirements and shipbottom paint performance may



prove useful in providing a quick estimate of the potential value of various paint systems. It will be necessary to test a wider variety of paint formulations before this can be ascertained. At the very least, a current requirement test would be expected to point out the unusually good paints and the bad ones. Further refinements would probably be required to classify the moderately good paints or to tell at how low a film thickness a very good paint becomes a fair or bad one.

### Conclusions

It is apparent that too high current densities were applied in these tests and that control of the potential and hence of the current supplied to the painted steel, is necessary if damage to most paints is to be avoided.

Some paints, such as vinyls, are capable of withstanding high potentials and high current densities and hence their use with cathodic protection allows a safety factor in the event that there are accidental applications of high current.

Coatings with high electrical resistance, low permeability and good alkali resistance, like vinyls, markedly reduce the total amount of current required for protection over a period of time. This represents a considerable saving in anodic material or other source of current. It is likely that in many underwater marine corrosion situations, the most economical and the most positive protection can be obtained by first coating with such a paint system and then applying controlled cathodic protection.

With the types of paints studied, those shipbottom paint systems which inactivate without cathodic protection are the same ones that will be inactivated in a much shorter time by protective currents. It is possible that some anti-fouling paint systems on steel at lower current densities and for a long period of time may become inactivated.

Importance of the anti-corrosive undercoats in preventing inactivation and the accompanying accelerated corrosion is well demonstrated. Both cases of inactivation observed in this test were substantially eliminated by a better "barrier" coating between the anti-fouling paint and the steel. There is an interesting correlation between the current requirements of the painted panels under cathodic protection and the prevention of corrosion by these same paints without cathodic protection. This relationship will be explored further to see if some rough screening test for the corrosion prevention value of the shipbottom paints can be developed.

### Acknowledgments

The test program on which this paper is based was initiated by Frank LaQue of the International Nickel Company. Thomas P. May, of the same company, Hilary Humble of Dow Chemical Company, George Diehlman of the National Lead Company, Charles Jackson of Devco & Reynolds Company, S. C. Frye of the Bethlehem Steel Company and the writer collaborated in designing the test program, making available the necessary materials and in studying the results.

Harry Paterson and his crew at the Sea Horse Institute cheerfully did most of the work connected with panel preparation, painting and exposure. R. B. Teel, of the International Nickel Company per-

formed the formidable feat of rating this large group of panels, upon withdrawal from test and in realizing complete accord with the observations of those interested in the program.

The writer is particularly grateful to R. J. Eckart, Director of Research, C. A. Woolsey Paint & Color Company, Inc., for his encouragement and advice in studying the properties of shipbottom paints.

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### DISCUSSION

#### Discussion by Frank E. Cook, Bureau of Ships, Navy Dept., Washington, D. C.:

A little over a year ago when Mr. Devoluy's data was just becoming available we initiated a different kind of a study at Harbor Island in conjunction with Dow and International Nickel Co. We wanted to determine the effects of an applied electric current on certain underwater paint systems in which the potential of the panels was controlled at a constant value. We now have some preliminary results after 13 months' exposure which are thought to be of sufficient interest to mention.

The paint systems evaluated were the hot and cold plastic-anti-fouling paints and the vinyl anti-fouling paint system. Each paint system was tested in duplicate in the scribed and unscribed condition, and both with and without an applied current. The potential selected was 0.9 volt (saturated calomel half-cell), except that the cold plastic paint was duplicated at 0.8 volt. The actual potentials will average somewhat under these values, however.

Results to date indicate that all control panels (no current) are perfect—no corrosion and no fouling except in scribe marks. Further, the applied current has not adversely affected the vinyl or hot plastic paint systems. However, the cold plastic panels under cathodic protection show some blistering attributed to the applied current. The blistering is negligible on the panels held at the lower potential. In all systems, the current had prevented rusting in the scribe marks.

It is apparent from the test that 1) potentials of about 0.85 volt, even though controlled, can damage certain paint coatings. 2) Certain paints are more resistant than others, and 3) the current had no adverse effect on fouling inhibition. The toxic used in all cases was cuprous oxide. The test is continuing. The potentials have been increased from 0.85 volt to 1.0 to 1.05 volts. The series at the lower potential is being retained at about 0.75 volts.

An explanation is also offered as to why the

cathodic deposits occurred on the outside of the blisters, as described by Mr. Devoluy in his paper. In laboratory work on electrolytic descaling in sea water in which current densities are of the order of  $\frac{1}{2}$  amp./sq. ft., laboratory personnel have observed the formation of numerous small white flecks in the water immediately adjacent to the cathode. These flecks moved toward and appeared to become attached to the cathode. If this is a phenomenon of the mechanism of the deposition of cathodic deposits, as it appears to be, it would account for the deposits being on top of the blisters and not under them.

#### Author's Reply:

Frank Cook's report on the Bureau of Ship's later work is a valuable contribution. It carries our exploratory efforts to logical conclusions by the use of controlled potentials.

#### Discussion by Oliver Osborn, Dow Chemical Company, Freeport, Texas:

The author and the so-called "board of directors" are to be commended for taking the initiative on this project, because all marine corrosion engineers will be intensely interested in its outcome.

We have been carrying on similar tests in Freeport on a somewhat smaller scale, and I confirm Mr. Devoluy's statement that the applied potential (or current) is critical. Where he reports blistering on vinyls caused by cathodic protection at a potential of 1300 mv (sat. cal. ref.) we have had vinyls under protection for over two years at a potential of 920 mv and can detect no adverse effects from the cathodic protection. A like amount of blistering has occurred on both the protected and unprotected specimens. Coating thickness is estimated at from 5 to 7 mils.

#### Author's Reply:

Oliver Osborn's test data also confirms the importance of controlling the potential and checks the Bureau of Ships work in showing that at 0.85 to 0.92 volts there are some paints that are unaffected by the applied current.

#### Discussion by Risque L. Benedict, Naval Research Laboratory, Washington, D. C.:

In addition to the generally good results at Harbor Island, just mentioned by Mr. Cook, the Naval Research Laboratory, at the request of the Bureau of Ships, has been conducting cathodic protection experiments on eighteen reserve fleet vessels in a variety of water salinities ranging in resistivity from 40 to 1500 ohms-cm. Approximately half of the vessels were freshly painted just prior to the application of cathodic protection. A series of panel racks which included painted, scribed (all painted surfaces were prepared with sandblasting, wash primer and the conventional Navy hot plastic system 20-40 mils thick) and completely bare panels were immersed at three of the four sites chosen. Some panel racks were then grounded to ships receiving cathodic protection and others were allowed to freely corrode. The painted ships and the attached panels were kept in a controlled potential range of from  $-0.78$  to  $-0.88$

volts with respect to saturated calomel, as opposed to  $-1.2$  to  $-1.4$  volts for Mr. Devoluy's panels. The apparent current densities (underwater area divided by total current) required to maintain this potential range was from .08 to .50 milliamperes per square foot, substantially the same current density found by Mr. Cook at the Harbor Island tests. This represents about 1/1000 of the 500 to 600 milliamperes per square foot used by Mr. Devoluy.

This test has now been underway from 6 to 8 months. Periodic visual examination of the panels revealed no adverse effect on fouling inhibition, no blistering of paint and either no rust or only a superficial surface rust. The panels not receiving cathodic protection had heavy rust tubercles with pits forming under them in the case of bare metal. The fouling on bare areas in some cases was heavier than that noted on bare areas on protected panels, but anti-fouling properties for cathodic protection on the basis of this slight difference is not claimed. The painted surfaces on both protected and unprotected panels were generally free from corrosion and paint damage, except at the edges and paint-bare metal intersurfaces on the unprotected scribed panels where pitting attack had penetrated under the paint causing part of it to slough off.

Since it was realized that any results based on purely panel data are open to debate, plans have been made to drydock the test ships annually. It will then be possible to correlate more completely the effect of controlled cathodic protection on the hot plastic paint system.

#### Author's Reply:

We agree with Mr. Benedict that we were operating at too high a potential but wish to point out that his current values were obtained by dividing the total underwater area by the total current. We were interested in estimating the current available to rupture the paint films around imperfections or at abraded areas. The basis for our calculations of current density is described in the paper. Had we used the total area of the panel we would have obtained values more nearly of the order Mr. Benedict considers reasonable.

#### Discussion by L. P. Sudrabin, Electro Rust-Proofing Corp., Belleville, N. J.:

The "current required" referred to in this paper represents the actual current flow between the magnesium anode and the panel and is not necessarily the minimum current required to prevent corrosion at pinhole flaws of the coating. Current flow in excess of the minimum protective current will accelerate paint deterioration as discussed elsewhere. The control of the protective current flow when cathodic protection is used is of great importance to attain maximum effectiveness in a combination system of cathodic protection and a coating.

#### Author's Reply:

We thank Dr. Sudrabin for pointing out that the current readings obtained are not necessarily the minimum currents required for each panel. It would

have been more accurate to call these values "Current Accepted" by various paint systems rather than "Current Required" or "Current Demands."

**Discussion by Edmund C. Reichard, American Smelting & Refining Co., Barber, New Jersey:**

In the introduction, the author mentions the interaction of zinc plates with bronze anti-fouling paint on a wood boat. What is the purpose of placing zinc plates on a wooden boat? To date I have not found a satisfactory explanation for the placement of zinc plates on wooden boats, although this is evidently a common practice.

I would also like to discuss the use of the terms "cathodic protection" and "current requirements" that are freely used throughout this paper. The paint industry would protest loudly if we talked of the cost and effects of applying 600 mil coatings—coatings in excess of  $\frac{1}{2}$ " in thickness—and called this "painting." Likewise, I think that those interested in cathodic protection should object to mis-uses of the terms "cathodic protection" and "current requirements" to describe tests in which 500 to 600 ma./sq. ft. are applied when less than 10 ma./sq. ft. are required.

Under the section entitled "Inactivation" the author attributes the damage to paint films observed in this work as "the results of electrical violence." Except for this one recognition, the author continuously uses the term "cathodic protection" rather than "electrical violence," evidently with the approval of the well-known experts participating in this program.

The terms "cathodic protection" and "current requirements" do not imply impressing 500 to 600 ma./sq. ft. of current upon any and every structure. Cathodic protection involves impressing, through galvanic or other means, the minimum current density required to maintain a structure cathodic and thus control its corrosion. The minimum current density required to maintain a structure cathodic is known as the current requirement of the structure.

The author caught this meaning when he described the damage to paint coatings observed as "the results of electrical violence." He could more accurately

have reworded the title to his paper to read "Behavior of Ship-Bottom Paints Subjected to Electrical Violence," and used the term "electrical violence" throughout the entire paper wherever "cathodic protection" now appears. Similarly, "current flow" would have been more accurate to describe what happened in place of the term "current requirements."

**Author's Reply:**

Mr. Reichard's comments indicate that he does not appreciate our method of arriving at the current densities at abraded areas as represented by scribe marks. We readily agree that the cathodic protection features of this test were over-designed, but at that time, little was known about the effects of cathodic protection on ship bottom paints and it was felt safest to overdesign the preliminary work. Furthermore, in rough ship board service, it is not unlikely that potential controls will occasionally be disrupted. It is therefore important to know which types of bottom paints are the least affected by unusually high potentials and current densities.

The use of zinc plates in the stern areas of wooden boats is to reduce the corrosion of the metal appendages. Admittedly it is difficult to justify this practice when propellers, propeller shafts, struts and rudders are available in modern corrosion resistant alloys.

**Discussion by Allen L. Alexander, Naval Research Laboratory, Washington, D. C.:**

In our work with cold plastic-type matrices a very definite point at around 25 percent pigment volume is reached above which paints may become inactive.

Our question was whether such a critical point had been established relative to vinyl matrices when pigmented with metallic copper.

**Author's Reply:**

We are unable to answer Dr. Allen Alexander's question about metallic copper in vinyl matrices because most of our work has been with the more economical, and corrosion-wise safer, cuprous oxide pigment.

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# Microbiological Corrosion of Buried Steel Pipe \*

By FRANK E. KULMAN

WITH a view to controlling the loss of pipe metal caused by stray railway currents from elevated and trolley lines, electrolysis investigations have been made on the gas pipes of New York City during the past 45 years. The remedy usually adopted has been to install insulating joints in the more important transmission and distribution mains, both cast iron and steel, bare and coated. Electrical drainage of stray currents to the railway sub-stations has not been applied by design to the gas mains. However, drainage of the electric cable sheaths has indirectly reduced the electrolysis hazard on the gas distribution mains and services, since the gas system is connected to the water system through metallic contacts in consumers' premises, and the water services are electrically in contact with the electric cables through ground connections. The result of this electrolysis work has been to reduce to a minimum the corrosion leaks attributable to stray currents.

Beginning about 1930, it became apparent that leaks in gas pipes were occurring more frequently in areas where stray currents were not present. The shut-down of trolley operations has resulted in increased leak frequency. The cause of most of the new leaks was attributed to "soil corrosion," although a clear understanding of the soil corrosion process was lacking at that time. This led to the installation of coated pipe as replacement for bare steel pipe at locations where corrosion had occurred. Later a decision was made to use coated pipe in all additions to the high pressure system. Cathodic protection was applied to some of the more important steel mains to supplement the coating protection, and installations are under way to protect small portions of the distribution system in corrosive swamp areas with insulating joints, coatings and magnesium anodes.

While progress was being made on mitigating soil corrosion, the search for knowledge of the soil corrosion process continued.

As gas mains were uncovered to repair leaks caused by corrosion, tests were made on the pipe and soil to determine the corrosion conditions at the leak point and at test excavations on each side of the leak and 50 feet away. This made possible a decision as to the specific cause of corrosion at each leak.

The field investigations included the following:

- a. A sketch of the location
- b. Size, kind and age of the uncoated pipe
- c. Description of corrosion, e.g. pitting, scale
- d. Description of soil texture, color, aeration, drainage



FRANK E. KULMAN—Engineer with Consolidated Edison Company of New York, Inc., has been employed by that concern in testing and design work for 26 years. Most of this time has been devoted to investigating and solving electrolysis and corrosion problems on New York City underground cable and gas pipe. Active in committee work with AIEE, AGA and NACE, Mr. Kulman holds a BS degree from College of the City of New York and EE and MEE degrees from Polytechnic Institute of Brooklyn. He is a member of NSPE.

## Abstract

Early corrosion investigations in New York City were concerned with electrolysis caused by stray currents leaking from elevated and trolley lines. This problem was solved by installing insulating joints in the gas mains. Attention was then given to mitigating soil corrosion which is responsible for many of the leaks being experienced. Test data at 472 field excavations showed that the most severe corrosion usually occurred in the poorly aerated clay soils containing organic matter. Bacterial action was indicated in 81 percent of the locations of severe corrosion. This revelation prompted a detailed investigation of the bacterial influence in underground corrosion. Population counts of five types of anaerobic and aerobic bacteria were determined at corrosive locations, concurrently with measurements of moisture content, organic matter, aeration and pH of the soil and the presence of sulfide in the corrosion product. Seasonal variations in the soil moisture, aeration and population of anaerobic bacteria were found to be associated with the underground corrosion cycle. Following a discussion as to the probable mechanisms of bacterial corrosion, the need for further improvement of the soil redox probe developed in the American Gas Association investigation is indicated. This probe measures the reducing intensity of the soil and thus locates corrosion areas prior to installing the pipe.

- e. Pit depth measurements
- f. Hydrochloric test for sulfide in corrosion product
- g. Soil resistivity
- h. Soil pH
- i. Pipe potential to earth (using clean steel earth probe)
- j. Current flowing in pipe.

As the test data accumulated with increasing corrosion experience, it became possible to make statistical studies to determine the underlying causes of underground pipe corrosion.

## Analysis of Field Tests of 1943 to 1945

A statistical analysis of test data obtained at 243 excavations of 2-inch steel gas pipes in Queens is shown in Table I. Most of these mains had been installed for 15 to 20 years.

\*A paper presented at a meeting of Pittsburgh Section, National Association of Corrosion Engineers, March 6, 1952.

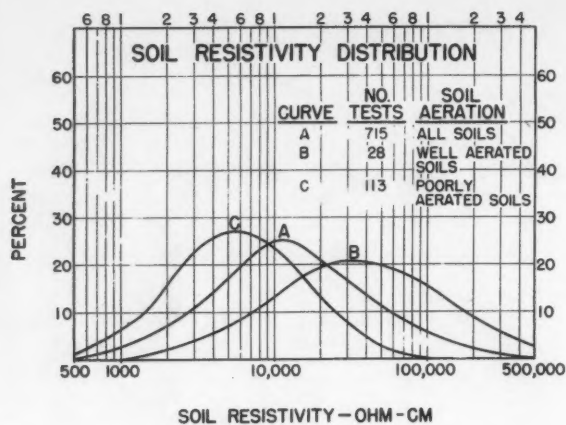


Figure 1—Soil resistivity distribution.

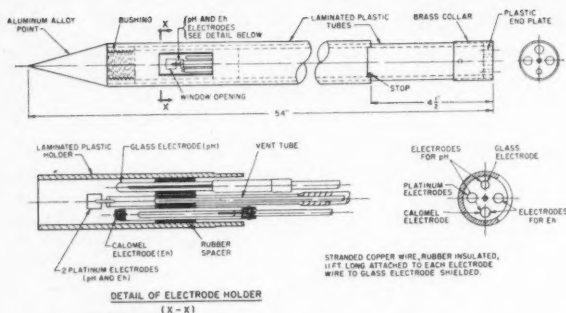


Figure 2—Redox probe for measuring soil corrosiveness.

TABLE I  
Statistical Analysis of Pitting on 2-Inch Mains  
1943-1945 Inclusive

	No. Statistics	DISTRIBUTION—PERCENT		
		Pitting 0-60 Mills	Pitting 61-120 Mills	Pitting 121-154 Mills
Total locations.....	243	31%	31%	38%
By Duration of Exposure:				
5.1 to 10 years.....	20	20	35	45
10.1 to 15 years.....	49	33	27	40
15.1 to 20 years.....	130	32	32	36
20.1 to 25 years.....	30	30	30	40
25.1 to 35 years.....	10	50	30	20
By Soil Texture:				
Clay.....	32	28	16	56
Clay with sand.....	63	22	29	49
Sandy clay.....	42	24	45	31
Sand with clay.....	83	40	37	23
Sand.....	20	50	15	35
By Aeration of Soil:				
Poor aeration.....	107	22	23	55
Fair aeration.....	101	37	42	21
Good aeration.....	30	50	20	30
By Drainage of Soil:				
Wet.....	99	19	28	53
Damp.....	108	38	35	27
Dry.....	31	48	26	26
By Sulfide Test of Corrosion Product:				
H <sub>2</sub> S odor strong.....	120	22	27	51
H <sub>2</sub> S odor moderate.....	20	25	45	30
H <sub>2</sub> S odor weak or absent.....	85	44	33	23
By Resistivity of Soil:				
500 to 8,000 ohm-cm.....	96	20	28	52
8,001 to 20,000 ohm-cm.....	76	39	29	32
20,001 to 500,000 ohm-cm.....	61	39	36	25
By Hydrogen-ion Concentration:				
pH less than 6.1.....	60	27	30	43
pH 6.1 to 7.9.....	132	26	30	44
pH greater than 7.9.....	2			
By Pipe-to-Earth Potential:				
Negative pot. more than 0.1 volt.....	10	30	20	50
Pot. between -0.1 and +0.1 volt.....	121	26	31	43
Pos. pot. more than 0.1 volt.....	98	38	31	31
By Pipe Current:				
Less than 0.5 amp. in pipe.....	216	30	31	39
0.5 amp. or greater in pipe.....	13	62	8	30

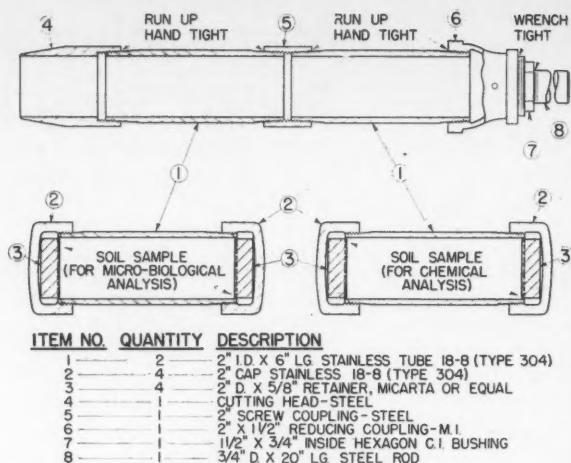


Figure 3—Soil sampling tube.

The most severe corrosion usually occurred in the clay-containing soils, further characterized by poor aeration, insufficient drainage and low resistivity. The products of corrosion often showed the presence of sulfide. These findings strongly suggested that anaerobic corrosion was involved.

Conversely, the pitting was found to be at a minimum in dry or damp, well-aerated sandy soils of high resistivity. Also there was less probability of sulfide in the corrosion products in these soils.

#### Analysis of Field Tests to 1949

The statistical study was broadened to include all field tests made in the 10 year period up to 1949. Results of the analysis of tests at 472 excavations of steel gas mains are summarized in Table II.

This study corroborated the previous finding that the most severe corrosion usually occurred in the dense, anaerobic, clay-containing soils in which organic matter was present.<sup>1</sup> Severe corrosion in the sandy soils was less frequent and when it did occur it was generally manifested as oxidation and slabbing. The average soil resistivity of soils associated with severe corrosion was 12,200 ohm-centimeters, with moderate corrosion, 25,600 ohm-centimeters and with slight corrosion 40,000 ohm-centimeters. Figure 1 shows the distribution of soil resistivity measurements. The hydrochloric acid tests on corrosion products gave evidence of ferrous sulfide in 81

TABLE II

Analysis of Tests at 472 Excavations  
1940-1949 Inclusive

No. of Excavations	Severity of Corrosion	Av. Soil Resistivity Ohm-Cent.	SOIL TYPE			SULFIDE TEST		
			Clay <sup>1</sup>	Sandy Clay <sup>2</sup>	Sand <sup>3</sup>	Pos.	Neg.	Test Not Made
185	Severe	12,200	103	59	23	139	33	13
141	Moderate	25,600	44	59	38	66	56	19
146	Slight	40,000	35	51	60	67	78	1
472	All Cases	24,500	182	169	121	272	167	33

<sup>1</sup> Poorly aerated soils.

<sup>2</sup> Moderately aerated soils.

<sup>3</sup> Well aerated soils.

percent of the cases of severe corrosion, 54 percent of the cases of moderate corrosion, and 46 percent of the cases of slight corrosion.

Although other factors were present, the results indicated a correlation between pipe corrosion and anaerobic conditions together with the possible activity of anaerobic bacteria. It was not possible to obtain a satisfactory correlation between pipe corrosion and soil pH, pipe potential and pipe current. Electrical tests, which had proved to be of great value in corrosion surveys of lead sheathed cables in ducts, were inadequate in evaluating the corrosiveness of soils in which pipes were laid. It was found that there were no clearly defined geographical areas in which the pipe corrosion was concentrated.

### Microbiological Investigation

Because of the foregoing experience it was decided to investigate the microbiological factors in pipe corrosion in greater detail and the services of a research laboratory were engaged to assist in this investigation, particularly in respect to the identification and counts of the soil bacteria.

The program of investigation included a thorough survey of the soil micro-organisms potentially capable of contributing to the corrosion of buried metal. A literature search revealed that the information available on the bacterial phases of corrosion was limited, although much good preliminary work had been done on the sulfate reducing bacteria<sup>2,3,4,5</sup> and on the development of the redox soil probe for measuring the reducing intensity of the soil.<sup>6</sup> Figure 2 illustrates the details of the redox probe presented by Starkey and Wight (Reference 6 and U. S. Patent 2,454,952). The proposed investigation was to be concerned with all major groups of bacteria which might in any way be involved in the corrosion process, whether by removing cathodic hydrogen,<sup>5</sup> by lowering soil resistivity,<sup>3</sup> by the production of acid end-products,<sup>7</sup> by encrustation, by film deposits, or other means.

### Soil Samples for Laboratory Analysis

An important technique prerequisite to this investigation was to find a means for collecting soil samples from the corrosion sites in such a manner as to assure that they constituted a reliable index of the soils in situ. A coring device was designed to insure minimum change in the pH, moisture content, temperature and aeration of the soil samples from the time of field sampling to laboratory study. Details of the device are given in Figure 3.

The sampling apparatus consisted of two stainless steel (Type 304) tubes, two inches in diameter and six inches long, coupled together, a steel cutting head attached to the leading tube and a steel follower rod attached to the follower tube. Before actual use, each part of the apparatus was wrapped and sterilized separately in the laboratory. In the field the coring device was assembled using aseptic technique wherever possible. The samples were obtained from soil adjacent to the excavated pipe by driving the device into the end wall of the excavation. Immediately before the sampling was done, the excavation was lengthened by one foot at each end to remove the soil exposed to aeration. Upon obtaining the soil samples, the tubes were disassembled and the screw caps were fitted tightly on each end of the tubes for shipment to the laboratory. In this manner two samples were taken simultaneously. The soil in the leading tube was used for microbiological examination, and that in the second was used for chemical analysis. Wherever possible, the soils immediately above and below the pipe and along each side were sampled.

Sterile nutrient media, adapted for the growth of the particular groups of organisms theoretically capable of influencing the corrosion process were employed for culturing the soils of each of the test site samples.<sup>8</sup> The method of dilution to extinction was used for obtaining the counts of bacteria per ml. The principal physiological characteristics of the bacterial types studied are summarized in Table III.

TABLE III—Summary of the Principal Physiological Properties of Microorganisms

GROUP AND TYPE	Oxygen Requirement	Soil Components Reduced or Oxidized	Major End Products	Habitat	Approximate Optimum Reaction pH	Temperature Limits °C
I. Sulfate—reducing . . . . . ( <i>Desulfovibrio desulfuricans</i> )	Anaerobic	Sulfates Thiosulfates Sulfites Sulfur Hyposulfides	Hydrogen sulfide	Water, muds, sewage, oil wells, soils, bottom deposits, concrete.	Optimum: 6-7.5 Limits: 5-9.0	Optimum: 25-30 Maximum: 55-65
II. Sulfur—oxidizing . . . . . ( <i>Thiobacillus thiooxidans</i> )	Aerobic	Sulfur Sulfides Thiosulfates	Sulfuric Acid	Soil composts, sulfur and rock phosphates, soils containing incompletely oxidized sulfur compounds.	Optimum: 2.0-4.0 Limits: 0.5-6.0	Optimum: 28-30 18-37 slow growth
III. Thiosulfate—Oxidizing . . . . . ( <i>Thiobacillus thioparus</i> )	Aerobic	Thiosulfates Sulfur	Thiosulfate to Sulfate and sulfur Sulfur to Sulfate	Widely distributed, sea and river water, mud sewage, soil.	Optimum: Close to neutral Limits: 7.0-9.0	Optimum: 30
IV. Iron Bacteria . . . . . ( <i>Crenothrix</i> and <i>Leptothrix</i> )	Aerobic	Ferrous carbonate Ferrous bicarbonate Manganese bicarbonate	Ferric hydroxide	Stagnant and running water containing iron salts and organic matter.		Optimum: 24 Limits: 5-40
V. Nitrate—reducing ( <i>Thiobacillus denitrificans</i> )	Facultative anaerobic or microaerophilic. Can live in absence of free oxygen in the presence of nitrate.	Sulfur Hydrogen sulfide Thiosulfates Tetrathionates	Oxidizes thiosulfates to sulfur, under anaerobic conditions, using nitrate as the hydrogen acceptor which is reduced to nitrogen.	Soil, peat, mud, canal and river water.	Optimum: 7.0-9.0 Limits: 5.0-10.0	Optimum: 30



TABLE IV—Data at Corrosion Test Sites—1948

IDENTIFICATION			PHYSICAL, CHEMICAL AND ELECTRICAL DATA										BACTERIAL POPULATION, PER ML.									
Site and Date	Excavation No.	Size Pipe, Years Installed	Depth Pitting, Inch	H <sub>2</sub> S Test	Pipe- Earth, Volts	Temp. °C.	SOIL			Resist. Ohm-Cm.	pH	Sampling Point	Sulfate, Qualitative	Moisture Percent	Organic Matter Percent	Sulfate Reducing	Sulfur Oxidizing	Thio-sulfate Oxidizing	True Iron	Iron Thread	Nitrate Reducing	Others
							Texture	Aeration, Drainage	Fair													
I—3-4-48	1	2" Steel 23 Yrs	.154	Weak	+4	1.5	Br. Sandy Clay	Fair	22,400	7.2	Above Pipe—E Pipe Level—W Below Pipe	+++++	+++++	+++++	+++++	0 10 20 10	200 10,000 20 10,000	10,000* 10,000* 1,000* 10*	0 0 0 0	0 0 0 0	+++++	10,000* 10,000* 1,000* 10*
II—3-30-48	1	2" Steel 11 Yrs.	.11	+	+2	8.0	Sandy Clay above pipe Sod at pipe level Clay below pipe	Poor	15,800	7.1	Above Pipe—E Pipe Level—W Below Pipe	Trace None Trace	7.9 22.7 15.0 12.2	0.7 13.3 3.3 1.3	10 100 1,000 10	200 2,000 2,000 20	0 10 1,000 10,000	10,000* 10,000* 1,000* 10*	0 0 0 0	0 0 0 0	10,000* 10,000* 1,000* 10*	
III—4-6-48	2	2" Steel 9 Yrs.	.154	Strong	+16	12.0	Gray mottled Clay	Poor	6,400	7.0	Above Pipe—E Pipe Level—W Below Pipe	Trace None Trace	11.7 9.6 16.4 14.7	1.4 1.4 3.5 1.5	1,000 1,000 1,000 1,000	2,000 2,000 2,000 0	0 0 0 0	0 0 0 0	0 0 0 0	100 1,000 1,000 1,000	10,000* 10,000* 1,000* 10,000*	
IV—5-18-48	1	4" Steel 23 Yrs.	.237	Strong	+20	13.0	Gray mottled Clay Br. Sandy Clay	Poor	14,000 22,000	7.1 7.2	Pipe Level	Trace	25.3	6.6	1,000	200	2,000	0	0	100	10†	
	2		.237	Strong	+20		Black Silt	Poor	4,200	5.1	Pipe Level	None	27.7	6.5	1,000	2,000	2,000	0	100	100	10,000†	
	3		.237	Strong	+20		Clay	Poor	9,000	6.5	Pipe Level	None	21.2	0.8	1,000	2,000	2,000	0	100	10	100†	
	4		.04	Weak	+04		Br. Sandy Clay	Poor	8,800	6.9	Pipe Level	Trace	12.3	1.4	100	2	2,000	0	0	100	0	
V—5-27-48	1	2" Steel 12 Yrs.	.14	Strong	-13	14.0	Br. Sandy Clay	Poor	5,400	7.7	Above Pipe—E Pipe Level—W Above and Below Pipe	None None None	13.9 12.3 13.3	2.9 3.8 3.4	1,000 100 100	0 0 0	2,000 2,000 2,000	0 0 0	10 100 100	100 1,000 10†	10† 10† 10†	
VI—7-1-48	1	2" Steel 20 Yrs.	.154	+	-20	23.0	Br. Sand	Fair	29,400	6.4 5.8 5.5 5.6	Above Pipe—E Pipe Level—W Below Pipe	None None None	5.5 10.3 11.6 14.9	0.7 0.5 1.3 Negl.	1,000 100 100 100	0 20 20 2	200 200 200 2	0 0 0 0	1,000 10 100 0	100 10† 0 0	0 10† 0 10†	
VII—7-23-48	1	2" Steel 10 Yrs.	.12	Strong	-08	27.0	Br. Clay	Poor	5,200	6.5 5.8 7.3	Pipe Level Pipe Level Pipe Level	None None None	12.5 15.3 16.1	5.7 2.5 4.0	1,000 100 1,000	200 2 2	20 0 0	0 0 0	10 0 10	10† 0 10†	10† 0 10†	
VIII—8-18-48	1	2" Steel 20 Yrs.	.154	Weak	-21	23.0	Br. Sand	Good	59,000	6.4 6.9 5.6 5.5	Above Pipe—E Above Pipe—W Below Pipe—E Below Pipe—W	Trace Trace Trace Trace	5.9 6.5 4.7 3.3	0.5 1.6 1.6 1.1	100 1,000 200 100	20 200 200 0	200 200 200 0	0 10 10 0	10 100 100 0	0 10 0 0	0 100 0 0	
IX—9-5-48	1	2" Steel 16 Yrs.	.154	Strong	-12	22.0	Br. Sandy Clay above Pipe Br. Clay at pipe level	Poor	9,800	7.3 6.8 7.1	Above Pipe—E Above Pipe—W Below Pipe—W	Present Present Present	12.4 12.1 11.9	2.6 2.6 2.4	1,000 1,000 1,000	20 2,000 2,000	20 2,000 2,000	0 0 0	10,000 1,000 1,000	100† 1,000 1,000	100† 1,000 1,000	
X—9-15-48	1	2" Steel 24 Yrs.	.154	Weak	-08	20.0	Br. Clay above Pipe Sandy Clay at pipe level	Fair	11,200	6.2 4.8 5.3 4.8	Above Pipe—E Above Pipe—W Below Pipe—E Below Pipe—W	Trace Trace Trace Trace	23.0 21.4 14.8 6.1	2.6 4.9 4.0 1.4	10 1,000 100 1,000	2 2,000 2,000 0	200 0 0 0	0 10 10 0	100 10 10 0	100† 0 10† 0	100† 0 10† 0	
XI—10-29-48	2	2" Steel 23 Yrs.	.154	Weak	+08	12.0	Br. Sand and Clay	Fair	10,400	4.8 6.0 6.4	Above Pipe—E Above Pipe—W Below Pipe—E Below Pipe—W	Trace Trace Trace Trace	17.6 17.2 3.2 3.0	5.4 3.2 0.8 0.6	1,000 1,000 1,000 1,000	2,000 2,000 2,000 2	2,000 200 200 0	0 10 10 0	10 10 10 0	10 10 10 0	0 0 0 0	
	1		.14				Br. Sand and Clay	Fair	14,800	4.8												
	3		.13				Br. Sand and Clay	Fair	51,500	6.1												

\* Aerobes † Anaerobes ‡ Not determined

Isolation of methane producing bacteria, although proposed in the initial outline of the work, was not undertaken because of the large number of samples required to be cultured under an atmosphere of methane and air.

Physical and chemical analyses of the soil were made to determine the moisture, organic matter, sulfate, sulfide, oxygen and the soil reaction (pH).

Eleven sites of pipe corrosion were investigated between March and October 1948. In addition to the laboratory determinations on the soil samples, field measurements were made of the pitting depth, sulfide in the corrosion product, pipe-to-soil potential (using a clean steel electrode), soil temperature and soil resistivity. The results of the 1948 investigation are tabulated in Table IV.

### Results of Bacterial Investigation

A study of the data in Table IV revealed that the intensity of the corrosion process varied cyclicly throughout the year. Although data were obtained from eleven sites at different times during the year it was possible to detect seasonal variations in the measured quantities.

The hydrochloric acid test for sulfide in the corrosion products gave "strong" indications in five sites, "weak" in four and was not determined in two sites. The "strong" indications were obtained during the period between April and September. At the laboratory the presence of sulfide in the soil was detected only in two of the samples removed from site IV in May.

Pipe potentials to steel test electrodes in the soil tended to be positive during the winter months and negative in the summer.

Aeration of the soil was observed to be "poor" at six sites, "fair" at four sites and "good" at one site. The "poor" aeration was observed at sites visited between March and September.

No single group of micro-organisms was indicated as the sole potential biological agent at any of the sites. There was co-existence of aerobes and anaerobes, of forms that bring about oxidation and those chiefly concerned with reducing reactions and of forms differing widely in the range of soil reaction required for their optimum activity. These data suggested that microbiological corrosion might not be a process involving only a single bacterial species but rather a mechanism in which several species might be the causative agents under environmental conditions favoring their respective development and activity.

The nature and extent of the bacterial population in soils is influenced by a variety of factors. Among the chief of these is the composition of the soil, the available food supply and environmental conditions such as moisture, aeration, temperature and soil reaction. In the corrosive sites tested, the soils varied from practically pure sands of 59,000 ohm-centimeter resistivity to dense clays with fills of black silt and sod, with resistivity of 3000 ohm-centimeters. The organic matter contents of the fills of black silt and sod were very high, 6.5 and 13.1 percent respectively and the sandy soils frequently showed the presence

of fragments of partially decomposed organic matter, remains of tree roots and other vegetation. All soils showed sufficient moisture to support the active growth of bacteria.

While the reaction of the soils ranged between pH 4.6 and 8.8 the majority of the samples were neutral or nearly neutral, a range particularly favorable to the activity of the sulfate-reducing bacteria. In several sites, local variations in the soil accounted for wide variation in this factor over short distances, as in site IV where pH varied between 4.6 and 7.3. Soil stratification may account for part of these variations. Seasonal variation of soil moisture may also influence the reaction.

### Tests on Seasonal Variation of Corrosion

As stated above, the study of the test results obtained in 1948 indicated seasonal variations in corrosion intensity. In 1949, therefore, it was decided to investigate the seasonal variation of corrosion at site IV which was located in an area where periodic excavation of the pipe was possible. At each sampling period, three excavations were made and approximately 12 soil samples were obtained. The results of tests made during March, May, July and October are summarized in the following tables:

It is noted from Table V, that soil moisture and reducing bacteria counts were at a maximum in May. The soil temperature reached its maximum several months later (July). The soil reaction, which is regarded as a measure of the anodic corrosion rate, showed greatest concentration of hydrogen ions in May.

With respect to the locations of the soil samples, the analysis given in Table VI indicates that during the spring and summer there were more reducing bacteria below the pipe than above. Consistent with this finding, the aerobic bacteria were more numerous above the pipe than below. In view of the limitations to obtaining accurate bacterial counts the results

TABLE V  
Summary of Measurements at Test Site IV  
(Average Values Shown)

	March	May	July	Oct.	Average
Soil Temperature °C.....	8.0	13.0	20.0	17.0	14.5
Soil Moisture Content, percent.....	19.2	21.9	16.9	14.9	18.2
Soil Reaction (pH).....	6.75	5.4	5.95	6.25	6.1
Organic Matter, percent.....	7.2	6.3	5.5	5.2	6.0
Reducing Bacteria, no. per ml.....	1890.	6250.	577.	14.	2180.
Oxidizing Bacteria, no. per ml.....	3390	3170	3140	2090	2950

TABLE VI  
Analysis of Bacterial Populations Above and Below Pipe  
(Average Values Shown)

Locations	Reducing or Oxidizing Bacteria	March	May	July	Oct.	Average
Above Pipe	Reducing.....	3440	5070	410	14	2230
Above Pipe	Oxidizing.....	4040	3500	3440	2160	3290
Below Pipe	Reducing.....	350	7440	740	14	2130
Below Pipe	Oxidizing.....	2750	2840	2840	2020	2610
	All Reducing....	1890	6250	577	14	2180
	All Oxidizing....	3390	3170	3140	2090	2950

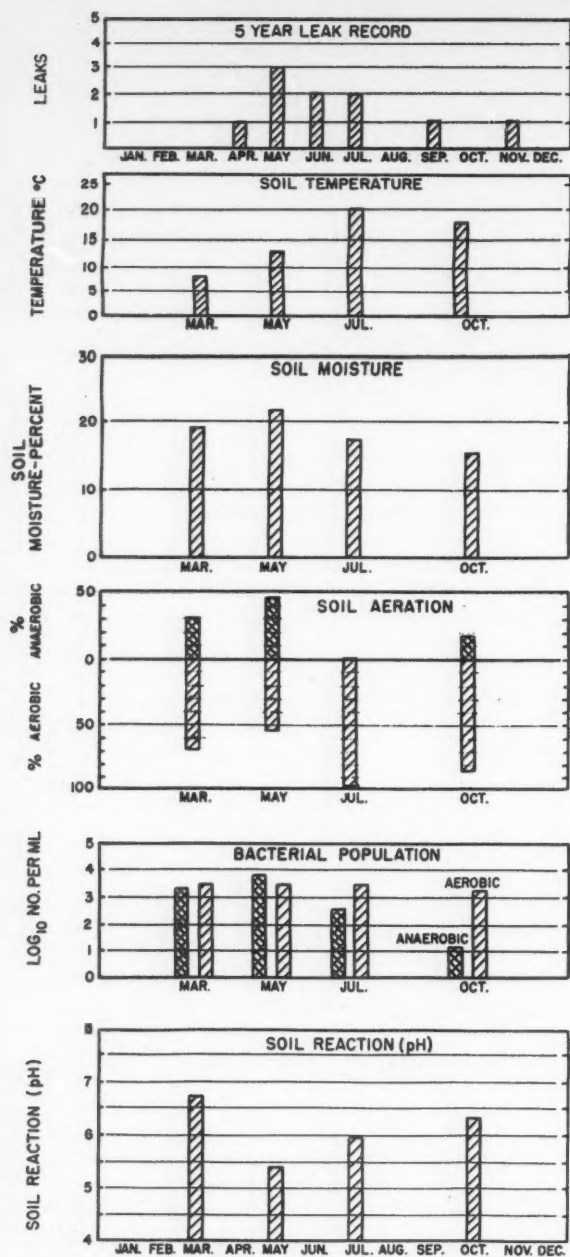


Figure 4—Correlation between corrosion and soil characteristics.

shown in Table VI are considered suggestive and not conclusive.

In figure 4 are plotted the seasonal variations of corrosion leaks, soil temperature, soil moisture, anaerobiosis, bacteria counts and soil reaction at test site IV. These results again show that the late spring is the period when anaerobic bacterial corrosion is most active.

In figure 5 are plotted the bacterial counts of each group of bacteria measured in March, May, July and October. The seasonal variation of bacterial counts of the reducing species is apparent.

The source of energy for most soil bacteria is the organic matter in the soil. The organic content of the

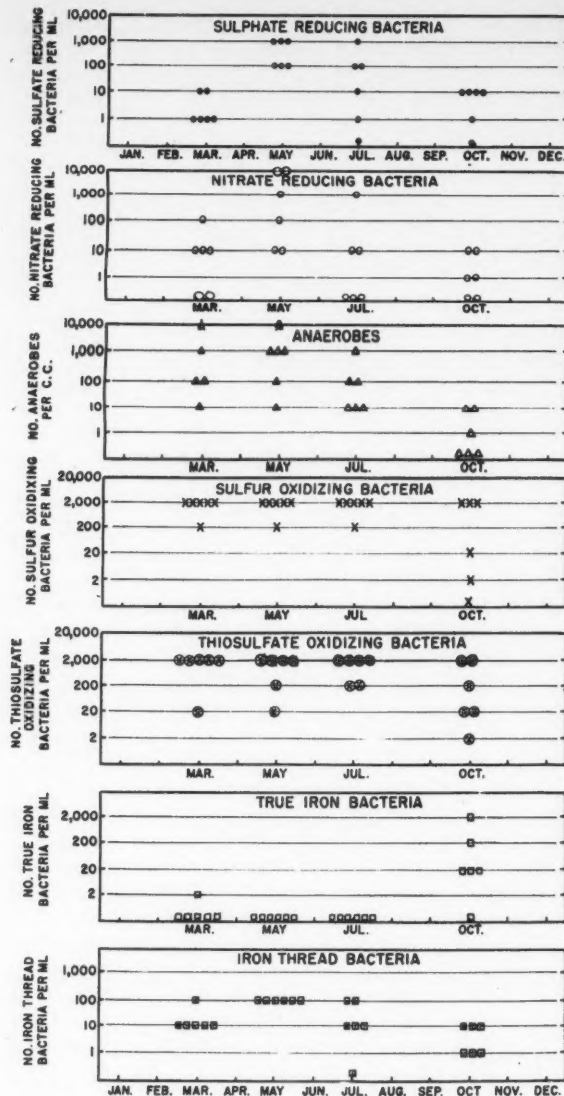


Figure 5—Seasonal variation of soil bacteria.

soil is not fixed but varies in cycles as described in detail below.

### The Cycles of Nitrogen, Carbon and Sulfur

Organic matter, which at a given moment may be alive or dead, goes through a cycle of life and death in nature.<sup>9</sup> In its living form, organic matter is characterized by a complex, organized structure which is part of plant or animal life. Upon death, organic matter is attacked by living organisms which decompose it into simpler compounds, some of which are organic and others inorganic or mineral. The cycles of carbon, sulfur and nitrogen are shown in Figure 6. It is of interest to observe that the left side of the cycles portray living matter, and the right side dead matter. The right side is of significance in soil corrosion.

Oxygen is required by the saprophytic bacteria in the decomposition of organic matter. This may be obtained from the oxygen dissolved in soil waters, or,



under anaerobic conditions, from the nitrates, carbonates and sulfates in the soil. Microbiological activity is always accompanied by removal of a portion of the soil oxygen. If the oxygen is not replaced from the atmosphere as fast as it is consumed, reducing conditions will ensue. Decomposition, accompanied by deoxygenation, usually proceeds for several weeks before anaerobic conditions are reached. Under more favorable circumstances, such as in sewage conduits, anaerobic conditions with the accompanying formation of the odorous hydrogen sulfide may occur in a period as short as two days.<sup>10</sup>

The association of underground corrosion with anaerobic environment has been accepted for many years. The exact mechanism of the corrosion process, however, has not been clearly understood and different theories have been formulated to explain it.

### Mechanism of Microbiological Corrosion

As formulated originally in Holland, the concept of bacterial corrosion visualized the removal of the polarizing hydrogen at the metal surface by the sulfate reducing bacteria, which reduced the soil sulfates to sulfides.<sup>5</sup> Removal of the hydrogen permitted the corrosion process to proceed unabated. In this view, the bacteria, under anaerobic conditions, perform a function which ordinarily is done under aerobic conditions by oxygen, i.e., oxidation of the cathodic hydrogen to water. The acceptance of this mechanism assumes that no portion of the metallic structure is exposed to oxygen. However, experience in this country has shown that portions of most pipe lines lie in aerated soils and that even with completely anaerobic conditions, the depositing of a continuous layer of sulfide on the pipe has not resulted in a rapid rate of corrosion.<sup>11</sup> Removal of polarizing hydrogen theoretically can be effected by the microbiological reduction of nitrates and carbonic acid, as well as by sulfate reduction.<sup>5</sup>

Another view of the mechanism of anaerobic corrosion visualizes the bacteria as active in forming differential oxidation cells.<sup>4, 12, 13, 14</sup> The bulk of the work reported herein supports this concept. Under favorable conditions of growth, the saprophytic soil bacteria feed on organic matter near the pipe surface and deplete the oxygen content at local points in the soil. During the growth period, the oxide film on the buried metal surface is reduced, thus causing the local area of metal to become anodic with respect to adjacent pipe areas in soil which is relatively more aerated. The galvanic cell thus set up may have a voltage in the neighborhood of 0.2 to 0.3 volt. The reduction of sulfate to sulfide begins when the oxygen content has been depleted or when the reducing potential of the soil has been lowered to minus 200 millivolts.<sup>10</sup> It is thus seen that sulfate reduction is *prima facie* evidence of reducing conditions. Whether the sulfate reducers by themselves cause anaerobiosis has not been proved conclusively.

A third view of the mechanism of bacterial corrosion is suggested by the work of Rogers on internal corrosion of non-ferrous condenser tubes carrying contaminated sea water.<sup>15</sup> Products of microbial decomposition may be deposited on the metal surfaces.

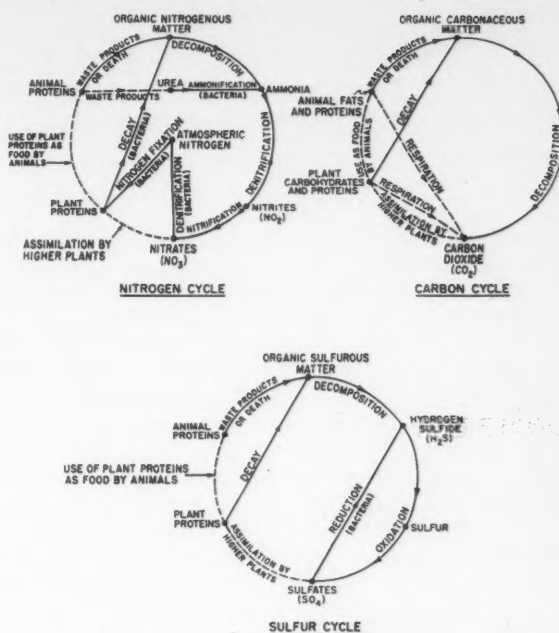


Figure 6—Nitrogen, carbon and sulfur cycles.

If the film is imperfect, bare areas of the tube may be corroded, probably by the galvanic potential between the metal and the deposited film which is cathodic to the metal. In the case of soil corrosion it has been suggested that a similar process may occur. Iron, for example, is anodic to ferrous sulfide which is formed microbiologically.<sup>3</sup>

In the processes mentioned above, anaerobic bacteria appear to play the dominant role. However, oxidizing species of bacteria also may be influential in causing corrosion of buried metals under aerobic or oxidizing conditions in the late summer.<sup>7</sup> Sulfur-oxidizing and thiosulfate oxidizing bacteria, respectively, oxidize sulfur and thiosulfates to acid end-products such as sulfuric acid and sulfate, which may cause chemical corrosion of the iron. The iron bacteria appear to oxidize ferrous salts to ferric hydroxide which may form tubercles over pits.<sup>12</sup>

In any actual case of underground corrosion it is probable that numerous species of bacteria are involved, each coming into play under environmental conditions favoring its respective development or activity.<sup>8</sup> The seasonal variations of temperature, moisture and aeration favor the greatest development of the reducing bacteria in the spring. Later in the summer and fall, when soil aeration increases, the reducing bacteria become dormant and the oxidizing species probably take the dominating role. Basically, however, it is the anaerobic bacteria which are generally considered of primary importance in underground corrosion.

### Practical Applications

Lest this discussion appear academic and of no value to the practical corrosion engineer, it should be pointed out that the studies of the Bureau of

TABLE VII

Soil Condition	PROTECTIVE MEASURES	
	Less Important Mains	More Important Mains
Slightly Corrosive.....	Uncoated Steel	Coatings
Moderately corrosive.....	Coatings	Coatings plus cathodic protection
Severely corrosive.....	Coatings plus cathodic protection	Coatings plus cathodic protection

Standards have emphasized the importance of soil aeration as a factor in corrosion of buried metals.<sup>16, 17</sup> In poorly aerated soils, the small available supply of oxygen is consumed in the depolarization of hydrogen at the cathodes. Because the soil is deficient in oxygen, ferrous ions migrating from the local anodes have little effect on the rate of corrosion. Hence, the initial rate of corrosion, though small because of the lack of oxygen available for polarization, continues unabated. In aerated soils, however, ferrous ions are oxidized and precipitated in close proximity to the anodes. Tubercles formed under these conditions prevent the further migration of ferrous ions and thereby stifle the corrosion. As a result, after a period of years the loss of weight and depth of pitting are greater in the poorly aerated soils.

Granted that corrosion is most severe in the poorly aerated soils, means must then be found for locating these potentially corrosive areas before actually laying pipe, so that the proper degree of corrosion protection can be provided. Until now the corrosion engineer has relied mainly on visual inspections, soil resistivity and acidity measurements to give an indication of soil corrosiveness. The soil redox probe developed by Starkey and Wight represents an advance in the measurement of soil corrosiveness since it indicates the degree of aeration of the soil. Unfortunately this probe in its present state is considered to be too fragile for use in most soils and requires further development into a rugged tool for field application before it can be widely used.

With the probe available at some future date, it should be possible for the corrosion engineer to make evaluations of soil corrosiveness and proportion the proposed protective measures to the soil corrosiveness in accordance with sound engineering and economic principles. For example in New York City, three classes of corrosion protection are applied to steel gas mains and the selection of the class of protection for each case is based on soil conditions and the importance of the main. The cases requiring the various degrees of protection are as follows:

### Conclusions

As the result of study of the corrosion problem on underground pipes and the special investigational work on the microbiological aspects outlined above, the following conclusions are suggested as a basis for future work:

1. Anaerobic bacterial corrosion is not so much a distinct type of corrosion as it is a new way of looking at what is generally regarded as soil corrosion. Microbiologically produced ferrous sulfide was found in 81 percent of the cases of severe corrosion.
2. A clue to the probability of bacterial action is poor soil aeration as shown, for example, by a black, mottled gray or bluish gray color in the upper sub-

soil. Soils having a uniform red or reddish-brown color are well aerated and usually are not considered corrosive.

3. The rate of anaerobic corrosion varies seasonally, being highest in the late spring. Correlation of bacterial activity with corrosion rate has been indicated.
4. It appears probable that the bacteria caused differential aeration cells to form on the metal surface by removing the soil oxygen at local points where organic matter is being decomposed. This results in the unaerated portion of the metal becoming anodic to oxidized portions in more aerated soils.
5. The development of the soil redox probe for measuring the reducing intensity of the soil should be completed. An instrument such as this should be useful in measuring the corrosiveness of the soils before laying pipe.
6. Fundamental research into the soil corrosion process should be expanded.

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# A Laboratory Method for the Study of Steam Condensate Corrosion Inhibitors\*

By HAROLD PATZELT\*

THE problem of corrosion of the internal surfaces of steam condensate return lines has been recognized for many years. Generally, the difficulties that have been experienced are the pitting, grooving and ultimate deterioration of sections of the condensate return system and the plugging of constrictions in the system with the insoluble products of corrosion. To properly evaluate the actual cost of return line corrosion, it is necessary not only to consider the loss in terms of labor, curtailed production and the cost of the material destroyed, but also to weigh effects in terms of inefficient operation of fouled equipment.

Experimental studies by various investigators<sup>1-5</sup> indicate that dissolved carbon dioxide and oxygen are responsible for practically all the corrosion in the condensate lines. The various expedients that have been devised for combating this attack are as follows:

1. The use of corrosion resistant alloys, which is generally prohibitive from a cost standpoint.
2. Minimizing the amount of carbon dioxide and oxygen in the condensate either by venting or pretreatment of the boiler feedwater.
3. Chemical treatment of the condensate.

This investigation has been confined to the latter means of corrosion mitigation.

Evaluation of corrosion inhibitors for return condensate systems has been the subject of several laboratory and field studies.<sup>6, 7, 8</sup> Analysis of results obtained by these investigators shows clearly that in order to obtain a more complete understanding of the action of inhibitors in condensate systems and the relative importance of the factors influencing them, the variables that affect corrosion must be carefully controlled. It is obvious that to obtain the control necessary for such an investigation it is essential that the work be done under laboratory rather than plant conditions.

The purpose of this paper is to present a laboratory method which has been used to evaluate steam condensate corrosion inhibitors. In this investigation an attempt has been made to control those variables which influence corrosion. Environmental conditions which have been considered are temperature, dissolved carbon dioxide and oxygen, pH, electrolytes, liquid velocity with respect to the metal and duration of attack.

## Abstract

A laboratory method for studying corrosion in steam condensate systems is described. In brief, a synthetic condensate is produced in a glass tower by aerating heated distilled water with a mixture of carbon dioxide and air. This condensate and a solution of the treatment are proportioned into a test container by gravity feed. A number of steel test coupons are suspended in the latter and the liquid is mildly agitated with a paddle stirrer. At periodic intervals a specimen is removed from the bath and the weight loss determined. The temperature, free carbon dioxide and dissolved oxygen of the synthetic condensate, and the treatment concentration are controlled throughout the test.

Corrosion test data are presented for synthetic condensate systems in which sodium hydroxide, sodium polyphosphate and neutralizing and film forming amines are used. The effect of pre-corrosion of the test specimen and of contamination of the condensate with boiler water on the functioning of several types of inhibitors are described.

The merits and limitations of the test method and possible interpretations of certain of the results are discussed.

## General Experimental Procedure

The test apparatus is schematically illustrated in Figure 1. A synthetic condensate was produced in a glass tower by aerating heated distilled water with a mixture of carbon dioxide and air. This condensate and a solution of the treatment were proportioned into a test container by gravity feed. A number of steel test coupons were suspended in the latter and the liquid was mildly agitated with a paddle stirrer. At periodic intervals a specimen was removed from the bath and the weight loss determined. The temperature, free carbon dioxide and dissolved oxygen of the synthetic condensate and the treatment concentration were controlled throughout the test. A more detailed description of the experimental equipment and procedure follows:

## Experimental Equipment

### Test Container

The vessel in which the corrosion tests were conducted consisted of a 12 inch x 12 inch cylindrical Pyrex jar. A two-section hard rubber top, reinforced with stainless steel plate, served as a cover plate for this bath.

A Nichrome wire specimen holder was mounted on the smaller section of the lid. The specimens were suspended from the wire on glass hooks arranged to position the coupons parallel to and about one inch from the inside of the container.

Controls and auxiliary equipment necessary to maintain equilibrium conditions in the bath were mounted through holes in the larger section of the lid. The liquid in the bath was stirred with a stain-

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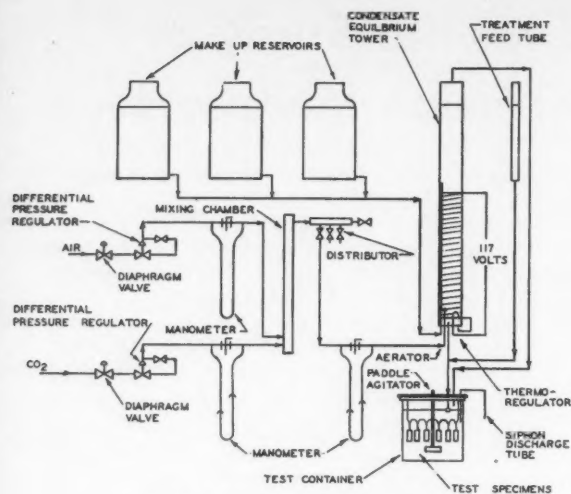


Figure 1—Corrosion test apparatus.

less steel paddle agitator rotating at 150 rpm in the center of the bath. Bath temperature was maintained with a 500 watt stainless steel sheathed immersion heater and a thermoregulator. Initial aeration of the bath was accomplished with a sintered glass diffusion disc. Gas composition above the surface of the liquid was controlled by discharging the spent gas from the "condensate equilibrium tower," into the gas space in the test vessel. The synthetic condensate inlet tube was equipped with a float valve assembly which maintained the liquid level in the bath about two inches from the top. The rate of discharge of liquid from the test container was regulated by adjusting the height of a siphon effluent tube which was connected to the bath through a copper cooling coil.

#### Synthetic Condensate System

Three 5-gallon bottles were supported above the test jar for replacement of the solution in the bath. A "condensate equilibrium tower" constructed from a 48 inch Pyrex tube 2 3/4 inches in diameter was mounted above the bath. Distilled water or its equivalent was discharged from the 5-gallon reservoirs into the middle of the tower through a rubber stopper in the base of the tube. The water was heated with a 500-watt heater which was constructed by wrapping the lower half of the tower with Nichrome resistance ribbon. Temperature of the water was thermostatically controlled at  $150 \pm 5$  degrees F. with a thermoregulator which extended through the stopper in the bottom of the tower. A disc type dispersion tube also was placed in this stopper so that the water could be aerated with a 5.4 to 1 mixture of air and carbon dioxide at the rate of 130 cc/min. The gas passing through the liquid in the tower was discharged to the test container through a stopper inserted in the top of the tower.

#### Treatment Feed

The treatment was metered into the bath from a Pyrex tube mounted above the test container and connected to the system between the outlet of the

tower and inlet to the jar. Depending on the solvent used to dissolve the inhibitor, the height of the feed tube above the bath was adjusted to compensate for the difference in the densities of the solvent and the distilled water. A soda-lime tube was placed in the top of the treatment tube to prevent evaporation and the absorption of carbon dioxide from the atmosphere.

#### Control of Gas Composition

Air and carbon dioxide were controlled by reducing the line pressure with diaphragm valves and controlling flow with a differential pressure regulator. Flow rates were measured with manometer type flow meters. Air and carbon dioxide were metered into a mixing chamber which was filled with 1/4-inch Berl saddles. This gas mixture was then discharged into a distributor from which it was metered into the aerator in the tower or test bath.

#### Specimens

Corrosion test specimens consisted of 1 inch x 2 inch panels which were sheared from a single sheet of 20-gauge cold rolled mild steel (approximately SAE 1020). All specimens were uniformly abraded with No. 2 emery paper, polished with No. 1 emery paper and rinsed with acetone and toluene before being immersed in the bath.

#### Experimental Procedure

##### Preparation of System

The test bath was filled with 4 1/4 gallons of dis-

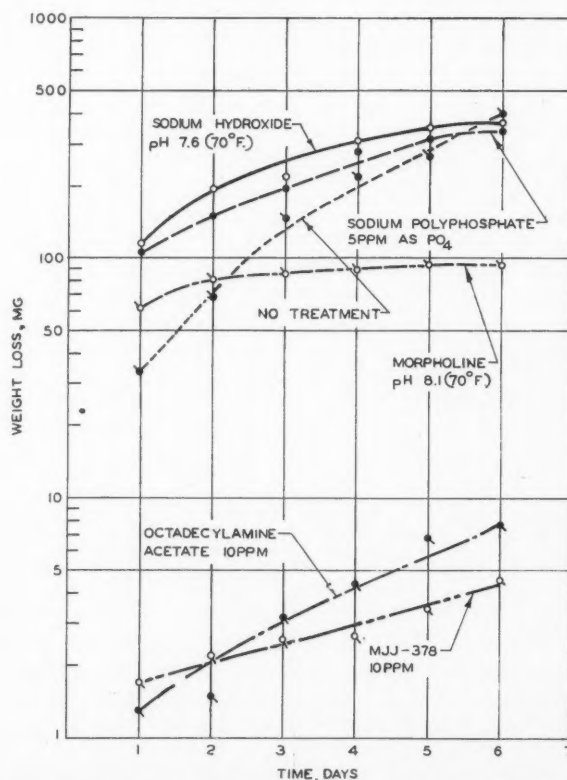


Figure 2—Corrosion of steel in condensate in the presence of inhibitors—Weight loss vs. Time.

tilled water or its equivalent. Agitation of the liquid was initiated and the water in the bath was heated to and thermostatically controlled at  $150^{\circ} \pm 1^{\circ} \text{F}$ . The free carbon dioxide and dissolved oxygen of the water were maintained at  $45 \pm 4$  ppm and  $3.5 \pm 0.2$  ppm, respectively, by aerating with a 5.4 to 1 mixture of air and carbon dioxide at the rate of 90 cc/min.

After equilibrating the bath in this manner for 24 hours, aeration of the bath was discontinued and initiated in the "condensate equilibrium tower." When the water in the tower was heated to  $150 \pm 5^{\circ} \text{F}$ , the regulated temperature, the effluent tube on the bath was lowered so that the liquid would be discharged from the bath at 26 ml/min. or 10 gallons per 24 hours. As soon as the system reached equilibrium, the required amount of treatment was added to the bath and treatment tube. The system was conditioned in this manner for 24 hours to eliminate the possibility of depletion of the inhibitor in the solution due to adsorption on the surface of the bath.

When a neutralizing type treatment was tested the gas being discharged from the "condensate equilibrium tower" was not directed over the surface of the liquid in the test bath but was vented to the atmosphere to prevent the excessive absorption of carbon dioxide by the neutralized condensate.

In tests involving the study of corrosion inhibitors in contaminated condensate systems, a synthetic boiler water of the following composition was added to the corrosion test container through an auxiliary feed tube:

Sodium hydroxide	340 ppm
Sodium chloride	340 ppm
Sodium sulfate	340 ppm
Sodium carbonate	170 ppm
Trisodium phosphate	70 ppm

#### Corrosion Test

Six of the test coupons were then weighed to the nearest 0.1 mg and placed in the test container. A specimen was removed from the bath periodically and was cleaned by  $\frac{1}{2}$ -minute immersions in inhibited muriatic acid followed by neutralization in a saturated sodium carbonate solution. When all the corrosion products had been removed from the coupon, it was rinsed with distilled water, dried by dipping in acetone and reweighed.

In those tests in which the effect of inhibitors on pre-corroded specimens was being investigated, eight specimens were weighed and placed in an untreated test container. After four days four of the coupons were removed and transferred to another corrosion test apparatus which had been pre-treated in the manner described above. A specimen was removed from each bath at periodic intervals and the weight loss was determined.

#### Analytical Procedure

Water samples were collected in 250 ml glass-stoppered Pyrex bottles through a glass tube extending to the bottom of the bottle to avoid entrained air bubbles, the absorption of atmospheric oxygen and the depletion of carbon dioxide in the liquid. A three-fold displacement of the liquid in the bottle was

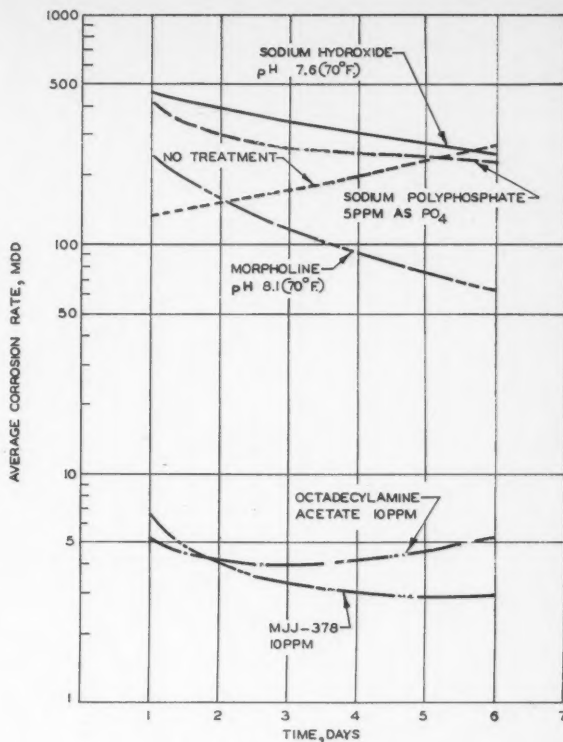


Figure 3—Corrosion of steel in condensate in the presence of inhibitors—Average corrosion rate vs. Time.

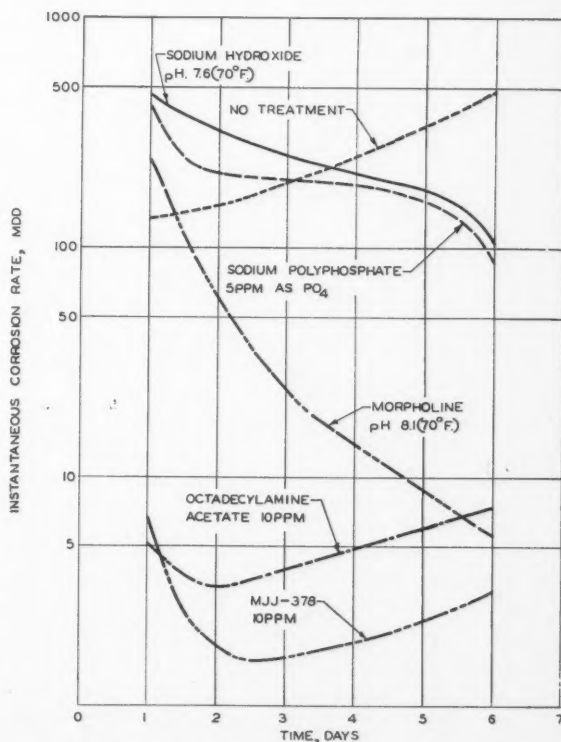


Figure 4—Corrosion of steel in condensate in the presence of inhibitors—Change in corrosion rate vs. Time.

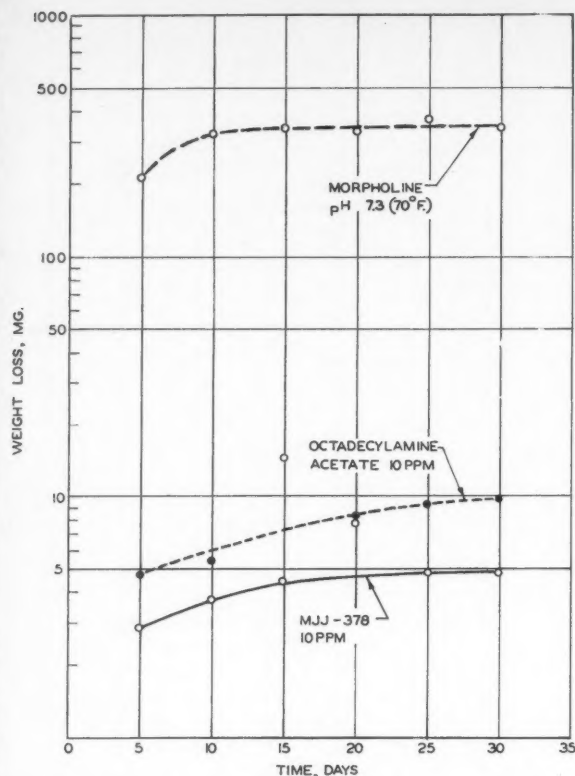


Figure 5—Corrosion of steel in condensate in the presence of inhibitors—Effect of long exposure on weight loss.

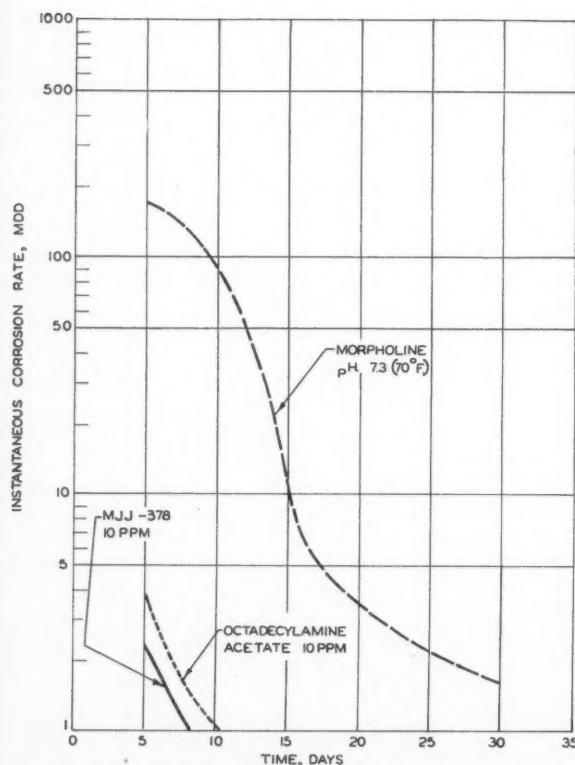


Figure 6—Corrosion of steel in condensate in the presence of inhibitors—Effect of long exposure on the change in corrosion rate.

allowed before stoppering, care being taken to exclude air bubbles. The free carbon dioxide of the condensate was determined at least once each day and occasionally a dissolved oxygen determination was made.

The dissolved carbon dioxide of the samples was determined by titration in an atmosphere of nitrogen with 0.02 N sodium carbonate, using phenolphthalein as an indicator. The water in the flask was mildly agitated throughout the titration with a magnetic stirrer to minimize the evolution of carbon dioxide.

Dissolved oxygen was determined by the ordinary Winkler method.

The pH measurements were made with a Beckman Model G pH meter equipped with a glass electrode assembly.

## Results

Water in the corrosion chamber for all experiments was agitated mildly at  $150 \pm 3^\circ \text{F}$  and contained  $3.5 \pm 0.2$  ppm of dissolved oxygen and  $45 \pm 4$  ppm of carbon dioxide in either free or combined form, depending on the type of treatment employed.

The inhibitors chosen for evaluation in this investigation represent several different classes of materials that are being used commercially to reduce corrosion in condensate return lines. For many years sodium hydroxide and morpholine, a volatile alkaline amine, have been used to neutralize the carbonic acid in condensates. Polyphosphate type treatments are being used with marked success in a number of steam generating plants. In recent years octadecylamine acetate, a hydrophobic film forming amine salt, has been recommended for the control of corrosion in condensate systems. The material MJJ-378 is a new film-forming or barrier type inhibitor which has been incorporated in Nalco No. 35FM.

A comparison of the corrosion of mild steel by condensate in the absence and presence of the several inhibitors discussed above is presented in Figure 2. Each point on the curves represents the actual weight loss by one of the specimens for the particular period of exposure indicated.

In addition to weight loss data, the average rate of corrosion and change in corrosion rate of these test coupons are presented also as a function of exposure time in Figures 3 and 4, respectively. The points for these rate curves were obtained from the weight loss vs. time curves presented in Figure 2.

Since there is always a question as to whether a corrosion test period is of sufficient duration, the more promising inhibitors, MJJ-378, octadecylamine acetate, and morpholine were tested for longer periods of time. The weight loss determinations and the changes in corrosion rates are presented as functions of time in Figures 5 and 6 and are substantially in agreement with the previous short term tests.

The problem of boiler water carry-over with the steam, due to foaming or priming, further complicates the study of corrosion in return condensate systems. The corrosion inhibiting properties of several inhibitors in condensate contaminated with 1 percent synthetic boiler water are compared in Figures 7 and 8.



In order to obtain uniform surfaces, most corrosion investigations utilizing inhibitors are conducted with polished metal specimens even though actual application will involve rough or corroded surfaces. The effects of precorrosion of the steel specimens on the functioning of MJJ-378, octadecylamine acetate, morpholine, and sodium polyphosphate are summarized in Figures 9, 10, 11 and 12 respectively.

### Discussion

The arbitrary environmental test conditions that were maintained in these investigations were chosen to simulate condensate systems in which severe corrosion has been experienced. In addition to the wide variety of test conditions that can be obtained with the apparatus as described, versatility can be increased by replacing the air supply with any mixture of nitrogen and oxygen desired.

Although flow conditions in the test vessel have not been correlated with those obtained in condensate return lines, it is believed the motion of the liquid relative to the metal specimens is representative of that occurring in practice.

Weight loss curves are presented for each test to acquaint the reader with the magnitude of the attack and to illustrate the precision of the experimental method, since the points on the curves were obtained from different test specimens. In the first series of tests the average corrosion rates of the test coupons were plotted as functions of time so that this conventional method of reporting corrosion test data might be compared with the change in rate curves. The advantages in reporting instantaneous corrosion rates is clearly demonstrated by the curves in Figures 3 and 4. A comparison of the average corrosion rates in condensates treated with morpholine, MJJ-378, and octadecylamine acetate after six days' exposure, would not indicate that the actual rates of corrosion at this point were practically identical.

The pH at which carbonic acid is completely converted to morpholine bicarbonate was calculated from the ionization constants of morpholine and carbonic acid. At 25° C this pH value is 7.3. The test with morpholine reported in Figures 2, 3, and 4, was conducted at a higher pH to determine whether corrosion inhibition would be improved. Results indicate that although satisfactory inhibition was obtained at both pH values, a longer period of exposure would be required to attain this condition at the lower pH value.

In this investigation, the neutralization pH values of the condensates treated with morpholine were reported rather than the concentrations of this inhibitor, since the former are the criteria used in the industrial application of this material to return condensate systems. Approximately 88 ppm of 91 percent morpholine were required to neutralize the synthetic condensate, containing 45 ppm of  $\text{CO}_2$ , to pH 7.3; and 134 ppm of the amine to obtain pH 8.1.

In all probability the test with sodium polyphosphate reported in Figures 2, 3 and 4 was not of sufficient duration to establish the effect of this material. An adherent black film was forming under the flaky, semi-adherent black coating that covered the surface of the test coupon and therefore ultimate protection of the base metal might have been obtained.

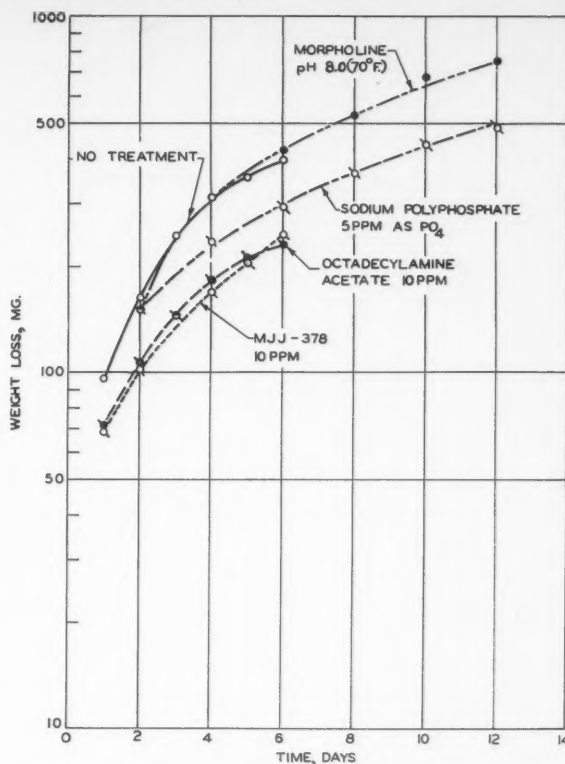


Figure 7—Corrosion of steel in condensate in the presence of inhibitors—Effect of boiler water contamination on weight loss.

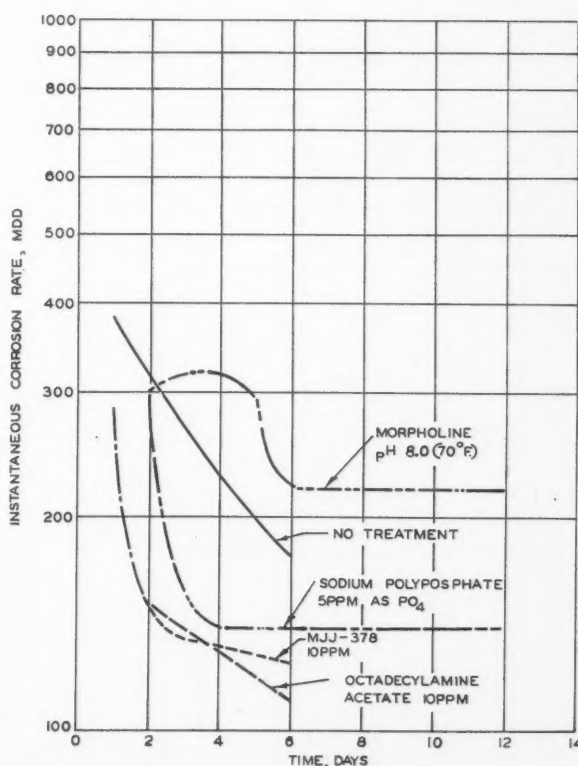


Figure 8—Corrosion of steel in condensate in the presence of inhibitors—Effect of boiler water contamination on the change in corrosion rate.

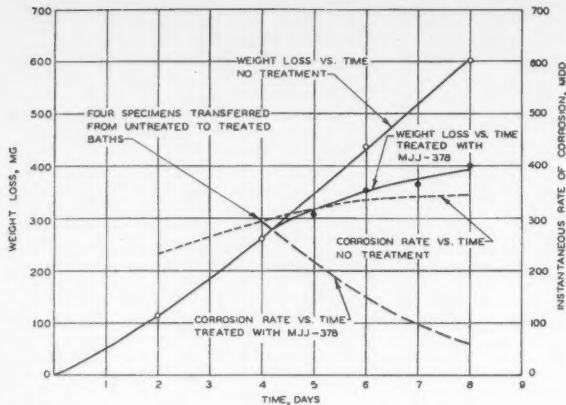


Figure 9—Protection of rusted steel in condensate treated with 10 ppm MJJ-378.

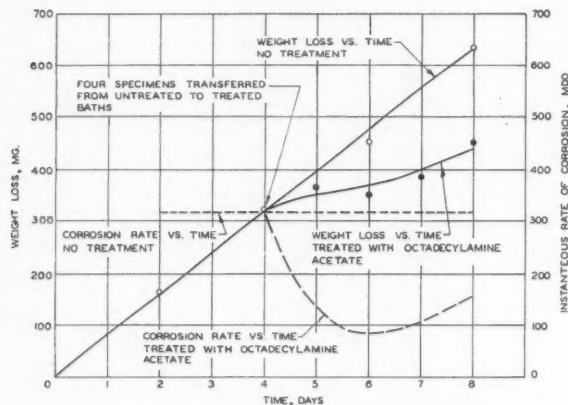


Figure 10—Protection of rusted steel in condensate treated with 10 ppm octadecylamine acetate.

The adverse influence of boiler water contamination on the effect of several inhibitors is illustrated in Figures 7 and 8. The pH of the contaminated condensate treated with morpholine was maintained at 8.0. This value was chosen because it was found that the addition of 1 percent synthetic boiler water to morpholine-neutralized condensate would raise the pH from 7.3 to 8.0. The decreasing rate of corrosion of the test specimens in the untreated condensate contaminated with boiler water indicates that some corrosion inhibition was obtained. This agrees with the field observations that plants having trouble with boiler water carry-over in the steam generally do not have corrosion problems as serious as in the absence of carry-over.

The rate of corrosion of the pre-corroded test coupons steadily decreased after being transferred to condensate being treated with MJJ-378, morpholine, or sodium polyphosphate. The inhibiting effect was more pronounced with MJJ-378. The reasons for the erratic corrosion rates of the pre-corroded test coupons in the system treated with octadecylamine acetate have not been ascertained.

Great care should be exercised in applying the results of these experiments to the rate of corrosion of steel pipe in actual practice where other factors than those considered here may have an influence. The corrosion of copper and zinc base alloys and the effect of partial immersion of the test coupons and intermittent treatment should be investigated if a more complete picture is desired.

It must be remembered that to evaluate properly a potential corrosion inhibitor for condensate return lines, the following information concerning the practical application of the material must be obtained:

1. Method of feeding the treatment into the condensate system and its ultimate distribution;
2. Properties of the material under boiler conditions, i.e., sludge and scale formation, foaming, corrosion, breakdown temperature, etc.;

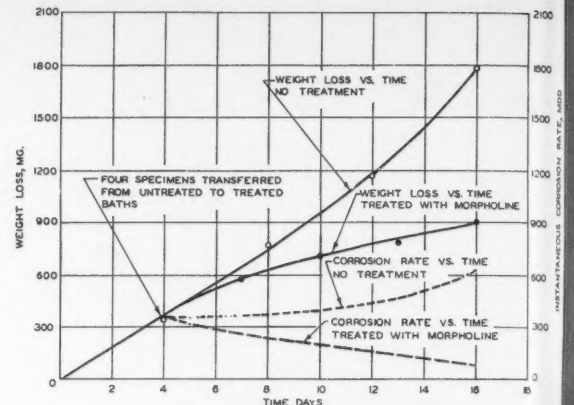


Figure 11—Protection of rusted steel in condensate neutralized with morpholine to pH 7.3 (70 degrees F).

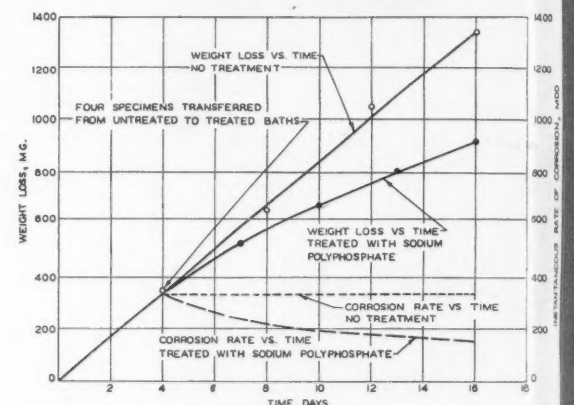


Figure 12—Protection of rusted steel in condensate treated with 5 ppm sodium polyphosphate as  $PO_4$ .

3. Toxicity of material and its volatile breakdown products; and
4. Fouling of heat transfer surfaces, turbines and other steam power equipment.

### Acknowledgments

The author expresses his appreciation to J. Green, not only for his suggestions and assistance in the experimental work but also for his help in the preparation of this manuscript. Acknowledgment is also made to A. Sterlin and M. Peat for their excellent assistance in the experimental work and to F. W. Sollo who conducted some of the preliminary investigations.

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THE surface for many of the industry in 1924, published a study of the effect of I that time than this the empirical corrosion the problem of condensate attention of the committee of Ica and T of Corro largely u pended co ing well. nately, g War II rials for Theoretic ion, how problem. rosion ra and sour all were and at n of oil pr some oil were not sive bring cause of establish brine and of the me further s brines and Copson<sup>3</sup> neutral u factory a In the tested at tured at t of pressu

\*A paper presented at the Gulf oil c

# Laboratory Apparatus for Studying Oil Well Subsurface Corrosion Rates And Some Results\*

By PAUL J. KALISH, J. A. ROWE, JR. and W. F. ROGERS\*

## Introduction

THE basic causes of corrosion of oil well subsurface equipment have been largely unknown for many years. It is believed that the first effort of the industry to study this matter scientifically was in 1924, when the Gulf Production Company established a corrosion fellowship at The Mellon Institute of Industrial Research under Stanley Gill. From that time until 1943 oil well corrosion studies, other than this one, received only scattered attention, with the emphasis being on corrective measures and corrosion resistant materials of construction. In 1943 the problem of corrosion in high pressure sweet condensate wells arose and received much concerted attention from the Condensate Well Corrosion Committee of the Natural Gasoline Association of America and TP-1 Committee of the National Association of Corrosion Engineers. Since this problem is now largely under control, greater efforts are being expended on the problem of corrosion of brine-producing wells of both the sweet and sour types. Fortunately, great progress has been made since World War II in the matter of finding economical materials for down-the-hole treatment of such fluids. Theoretical work on the basic causes of the corrosion, however, has not yet adequately explained the problem. Rogers and Shellshear<sup>1</sup> measured the corrosion rates of corrosive and non-corrosive sweet and sour brines in the laboratory and concluded that all were non-corrosive when produced free of oxygen and at neutral pH values. Rogers<sup>2</sup> studied the effect of oil produced along with oil well brines and found some oils to be protective in nature, whereas others were not. This establishes the fact that some corrosive brines may not destroy metal equipment because of the protective effects of the oil. It also establishes the fact that a combination of a corrosive brine and non-protective oil will result in corrosion of the metal equipment. In view of the earlier work,<sup>1</sup> further studies are necessary to determine why some brines are corrosive under oxygen-free conditions. Copson<sup>3</sup> has reviewed the literature on corrosion by neutral unaerated oil well brines and finds no satisfactory answer to the problem.

In the earlier work by Rogers the fluids were tested at pH values corresponding to those measured at the well head. It is known that the release of pressure on oil well brines results in a loss to the

## Abstract

An apparatus has been constructed for studying the corrosion rates of oil well brines under conditions simulating those at the bottom of the well. It has been found that when carbon dioxide or hydrogen sulfide is recombined with a well fluid to underground conditions the fluid is frequently acid in character. Such acidity, coupled with a high fluid temperature, and the absence of an oil with protective properties, is believed a primary cause for high subsurface corrosion rates. A method of testing inhibitors is described. Data are presented showing mercaptans to act as inhibitors of corrosion. Such compounds could be naturally occurring inhibitors of sulfide fluids.

atmosphere of acid gases such as carbon dioxide and hydrogen sulfide. It was decided to construct a test apparatus wherein oil well brines could be recombined with acid gases to bottom hole conditions and determine the bottom hole pH values and the resulting corrosion rates and correlate these with field experience.

## Apparatus and Test Procedure

A closed circulating system consisting totally of glass and rubber connections was chosen as the most suitable for the study. Minimum and maximum fluid volumes for proper circulation conditions range from 150-350 cc, under pressures ranging from 24 mm of mercury (vapor pressure of water at 77 degrees F) to 1300 mm of mercury gas pressure. Thus it is possible to test brines under oxygen free conditions and under partial pressures of acid gases up to 25 psia. A temperature range of room temperature to 160 degrees F is obtainable by means of a thermo-regulated circulating jacketed water bath containing a 500-watt heater. A flow diagram of the

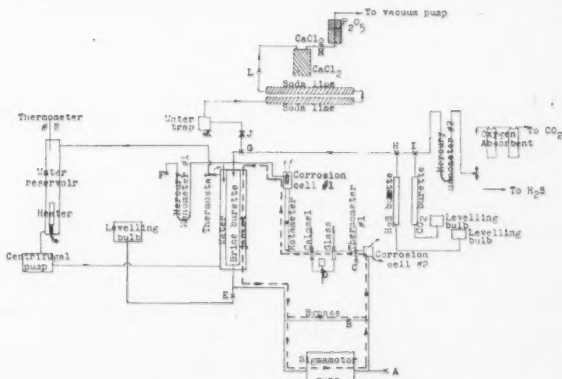


Figure 1—Flow diagram of corrosion-recombination apparatus.

\*A paper presented at the Eighth Annual Conference, National Association of Corrosion Engineers, Galveston, Texas, March 10-14, 1952.  
\*Gulf Oil Corporation, Houston, Texas.



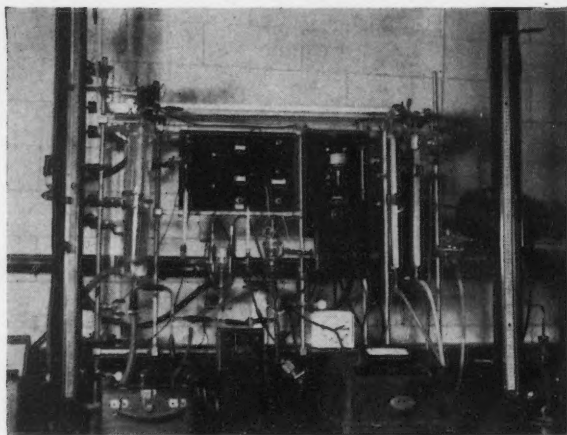


Figure 2—Corrosion-recombination apparatus.

constructed apparatus appears in Figure 1 and a photograph in Figure 2.

The main circulating system includes a 250 cc burette, Model T-6 Sigmamotor pump, thermometer, glass electrode, calomel electrode, rotameter, metal galvanic electrodes and a pump bypass connection. This main system is indicated in the figure by a dotted line. The brine is admitted through pinch valve E into the 250 cc burette. The Sigmamotor pump circulates the brine at a rate which is controlled by adjustment of the bypass valve B. The volume of fluid circulated per unit time is indicated on the float-type rotameter which has a range of 0-1000 cc/minute. Brine temperature is read on the thermometer above valve C. Valves A and C are for drain purposes. A glass electrode and a calomel electrode are installed in the U tube in the circuit to give pH measurements. Valve D is a three-way stopcock which serves the purpose of either admitting liquid to the system through a thistle tube or removing liquid through a drain attachment. The brine is circulated into the 250 cc burette through a small orifice which results in good mixing with the gas in the vapor space.

Corrosion cell No. 1 consists of two dissimilar metals suspended in the brine by electrical leads which pass through a rubber stopper. The electrodes are insulated from each other by means of rubber tubing rings. The pressure on the circulating system is indicated by manometer No. 1 which is opened or closed to the atmosphere through pinch valve F. Corrosion cell No. 2 has been added to the apparatus since the completion of the work discussed in this paper and will be used for further study of acid brine behavior.

The 250 cc burette is enclosed by an outer jacket which contains the heating water and a mercury-to-wire type thermoregulator. This water is circulated around the burette and into the heater reservoir by means of a small stainless steel centrifugal pump. The reservoir is equipped with a thermometer as a check on the brine thermometer.

Dissolved gases which are present in the brine are removed by the vacuum pump through an absorption train. As a protection to the pump, acid

gases are picked up by two tubes of soda lime in series. Water is removed by passage of the vapor through calcium chloride followed by phosphorous pentoxide. Valves L and M are installed to keep atmospheric leakage overnight at a minimum. A water trap collects the moisture which condenses before entering the absorption train; valve K is a drain for the trap.

After the system containing the brine has been evacuated, acid gases are introduced through the gas burettes at the right. Valve G is a 3-way stopcock which is used alternately to evacuate and charge the brine. Valve J closes off the vacuum unit when acid gas is being added or when a run is being made. Valves H and I are 3-way stopcocks which permit alternate use of the burettes. When carbon dioxide is injected the gas is bubbled through a vanadyl sulfate solution which results in removal of oxygen.<sup>4</sup> Hydrogen sulfide is added directly into the burette through mercury manometer No. 2. When gas under pressure higher than atmospheric is required, nitrogen pressure is applied to the burette liquid through the levelling bulb. For specific cases, other gases such as oxygen, air, nitrogen, or ammonia may be injected either through the burettes or bypassing the burettes directly through the manometer.

A panel board not shown in the flow diagram controls the electric circuits in the system. The leads from the two electrodes in corrosion cell No. 1 are connected through an on-off switch across a 6.7 ohm resistor. Also across the resistor is the millivoltmeter, which has a scale range of 0-18 millivolts. When testing a brine the normal internal resistance of the cell is about three ohms. This results in a total series circuit resistance of a little less than 10 ohms through which the generated corrosion current flows.

The calomel reference electrode and the glass electrode are connected to a Beckman Model H2 AC glass electrode pH meter which facilitates continuous pH readings. As a means of measuring the electrode potentials a potentiometer (Leeds & Northrup 0-1 volt range) is employed. The calomel electrode is used as a reference and connected to one post on the potentiometer. The two metal elements are connected alternately during the corrosion runs to the other potentiometer post. In this manner it is possible to compare the effect of a variation in pH and other factors on the potential of both the anode and the cathode.

The apparatus as described is used for brine testing only. Because of the construction of the circulating system a mixture of oil and brine would result in only the brine being circulated unless the total brine present were less than 50 cc. In any event, circulation of oil through the system would cause considerable difficulty in maintaining a clean apparatus.

As mentioned previously, the pressure is limited to 25 psia by the fact that rubber and glass components are used. The jacket water may not be heated to more than 160 degrees F with the 500-watt heater employed. Runs at higher temperatures would weaken the connections and result in damage to the pH electrodes.

The galvanic cell which originally was employed in the corrosion circuit consisted of a piece of copper foil and a No. 10 common nail. The foil was rolled into a cylinder  $\frac{1}{2}$ -inch in diameter by  $2\frac{3}{8}$ -inch in length. The nail was suspended inside the foil and insulated from it by two bands of rubber tubing. The foil was connected to a copper wire and the nail to an iron wire; both wires were drawn through a rubber stopper and connected to the panel board. The copper cathode-iron anode system proved quite satisfactory for runs on non-sulfide brines using carbon dioxide and oxygen as the corrosive gases. Several of these runs will be discussed at greater length when the experimental results are presented. However, when sour brines containing hydrogen sulfide were introduced into the system, a black deposit of copper sulfide formed on the foil surface and resulted in a change in polarity, causing the foil to be anodic to the nail.

It was therefore decided to investigate other metals for possible use as cathodes. A graphite nail suspended inside a piece of cold rolled steel pipe failed to produce a corrosion rate large enough to measure.

The next cell constructed consisted of a No. 8 common nail suspended in a cylindrical piece of cold rolled steel. In a  $\text{CO}_2$  brine the large element became anodic and corroded with the nail acting as the cathode. In an attempt to force the nail to become anodic an outside voltage source was employed.

Passage of current through the cell in such a manner as to make the nail corrode for several minutes resulted in no permanent change in the potential of either the pipe or nail. Subsequent hydrogen sulfide runs gave the same direction of current flow as with the carbon dioxide. In view of the fact that a large anode area and a small cathode area is undesirable and because of the greater possibility of local cell action, the iron pipe-iron nail cell was abandoned.

An iron-nickel cell was next constructed and was found to give satisfactory results. The nickel remained cathodic under both sulfide and non-sulfide conditions. A number of reproducible runs were made with the nickel pipe and No. 10 common nail.

The final cathodic material utilized was platinum foil. The foil was bent into a cylinder as was the copper foil. Platinum was selected because it is more likely to remain inert than any of the other readily available materials. The platinum foil-No. 10 common nail was used to evaluate all of the corrosion inhibitors tested and is the couple still in use.

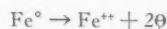
Corrosion in an iron-platinum brine system is a matter of depositing iron ions into solution at the nail anode and of removing molecular hydrogen at the platinum cathode. In an oxygen-free neutral brine the corrosion rate should be negligible because there is a restricted tendency, because of overvoltage, for the hydrogen ions which plate out to be removed. The presence of oxygen or an increase in solution hydrogen ion concentration will cause an increase in the rate at which these plated hydrogen ions will be removed, thereby increasing the corrosion rate. Some local corrosion will, of course, occur on the surface of the nail, but with a large platinum

surface available the majority of the hydrogen will be deposited on the cathode.

In unaerated waters which have high corrosivity, the effect may largely be due to development of low pH because of the presence of high acid gas concentrations. The temperature of the brine and velocity with which it moves over the corroding area also influence the corrosion rate. Other factors such as the physical structure and purity of the metal control corrosion, but do not generally vary much from one well to another. In the case where a brine known to have a low bottom hole pH is not apparently corrosive, it may be assumed that the produced oil or brine contains some natural inhibitor which forms a protective film on the metal surface.

The reaction in the laboratory corrosion cell, using an evacuated brine, may be considered as follows:

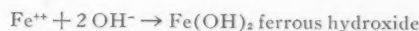
1. at the iron anode:



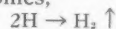
2. at the platinum cathode:



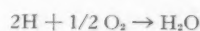
3. in solution:



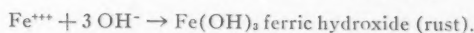
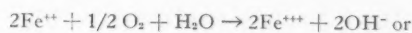
In the presence of high hydrogen ion concentration, reaction 2 becomes,



In the presence of oxygen, reaction 2 takes the form,



and 3 then goes to the ferric form,



It is possible, by knowing the surface area of a No. 10 common iron nail, to translate the millivoltmeter reading across the 6.7 ohm resistor to inches of metal lost per year. Using Faraday's law, removal of 27.925 grams of ferrous iron would generate 96,500 ampere-seconds of current. The average surface area of a No. 10 common nail (exclusive of the head which was not exposed), is 0.94 square inches, and the density of iron is 0.28 lb/cubic inch. Changing ampere-seconds to milliamp-years gives,

$$\frac{96,500 \times 10^3}{60 \times 60 \times 24 \times 365} = 3.06 \text{ ma-years}$$

Changing to millivolt-years gives,

$$3.06 \times 6.7 = 20.5 \text{ mv-years.}$$

Therefore, removal of 27.925 grams or 0.062 pounds of iron per year would give an average voltage drop across the 6.7 ohm resistor of 20.5 millivolts. In terms of inches penetration:

$$\frac{0.062}{0.28 \times 0.94} = 0.24 \text{ inches per year}$$

Therefore:

$$1 \text{ mv} = \frac{0.24}{20.5} = 0.0117 \text{ inches/year or } 11.7 \text{ mils/year.}$$

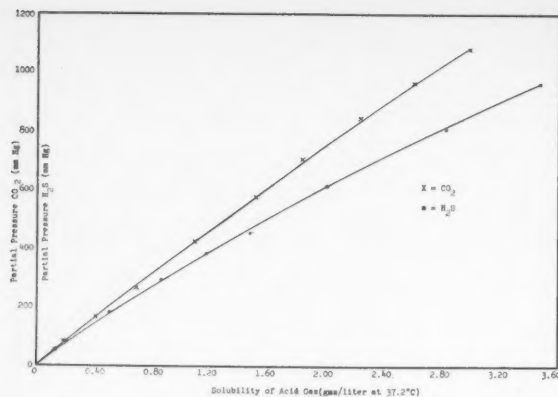


Figure 3—Kerosene and acid gas solubility curve.

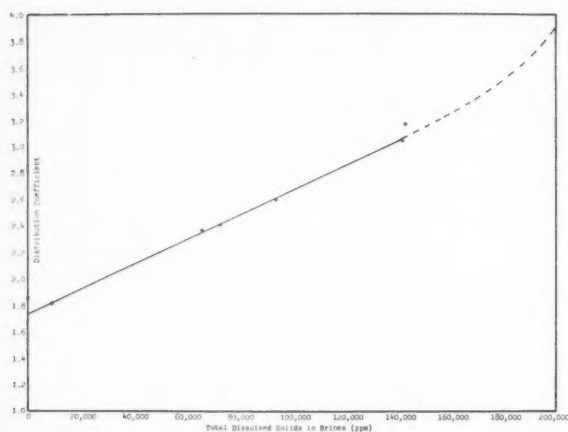


Figure 4—Relation of distribution coefficient to total solids in sweet brine.

#### Effect of Released Acid Gases on Bottom Hole pH Values

The initial phase of the study consisted of a recombination of produced acid gas and gas free natural brine as a means of determining bottom hole pH. In this study the galvanic corrosion cell was not utilized. A certain amount of field data was necessary before calculations could be made and subsequent bottom hole acidity determined.

For each well evaluated it was necessary to obtain the barrels of oil and water produced per day and the cubic feet of gas per day. In order to obtain a representative sample of the produced gas and fluid, a separator bottle was attached to a well head connection in such a manner that the gas was bled off into a gas tester and the water siphoned off into a gallon bottle. The oil remained in the separator bottle. The pH of the water was determined immediately with a glass electrode type pH meter for the well head pH reading. The gas was analyzed for carbon dioxide and hydrogen sulfide using conventional means. A bottom hole temperature of approximately 100 degrees F was taken as the basis for the calculations.

In order to determine that portion of the total acid gas present which is dissolved in the brine it is necessary to calculate a distribution coefficient between

the brine and the oil. The distribution coefficient is defined as the solubility of the acid gas in the oil divided by the solubility of the acid gas in the brine at the same temperature and pressure.

For ease of laboratory testing kerosene was selected as the oil standard. Curves of partial pressure vs. solubility at 99 degrees F for both hydrogen sulfide and carbon dioxide in kerosene were obtained. The curves are shown in Figure 3. For each brine tested in the laboratory a similar curve is plotted at the same temperature. From the kerosene and brine curves it is then possible to obtain values of solubility in brine and corresponding solubility in kerosene for any partial pressure of acid gas. At acid gas partial pressures from 0-1000 mm of mercury, brines with low alkalinity (0-200 ppm bicarbonate) had nearly constant distribution coefficients over the complete partial pressure range. In several tests on sour brines of high alkalinity, the distribution coefficient showed considerable variation over the 0-1000 mm range. An average distribution coefficient was obtained for the low alkalinity brines by averaging the values for partial pressure increments of 100 mm. In the case of the highly alkaline brines, the 1000 mm value was used, since this was assumed to correspond more nearly to bottom hole conditions.

Carbon dioxide solubility runs were made for a number of sweet brines and for distilled water. A hydrogen sulfide run was also made on distilled water. The distribution coefficients were calculated for each brine. For the carbon dioxide runs, the coefficients were plotted against total brine solids and yielded the curve shown in Figure 4. The fact that this curve is a straight line function up to 143,000 ppm is due to the low alkalinity of the brines tested. With more highly alkaline brines the brine phase would naturally be expected to retain more of the acid gas, thereby lowering the distribution coefficient. Table I shows the coefficients, dissolved solids and bicarbonate content for the brines tested. With the possible exception of the 500 ppm bicarbonate brine, the alkalinities can be considered sufficiently low that the carbon dioxide solubility is a function only of total solids. A check of Figure 4 shows that in this case the 500 ppm bicarbonate brine (66,000 ppm total solids) was also on the linear portion of the curve.

Typical non-sulfide and sulfide brines will be considered as a means of discussing the variation between well head pH and bottom hole pH. A high solids non-sulfide brine was introduced into the recombination apparatus and evacuated to an equilibrium pH value. Measured increments of carbon dioxide were subsequently added to give approxi-

TABLE I

Total Solids (ppm)	HCO <sub>3</sub> (ppm)	Distribution Coefficients	
		CO <sub>2</sub>	H <sub>2</sub> S
50	24	1.84	1.86
9,000		1.82	
66,000	500	2.37	
73,000	114	2.41	
94,000	155	2.60	
142,000	24	3.05	
143,000	24	3.17	
200,000	0	3.88	



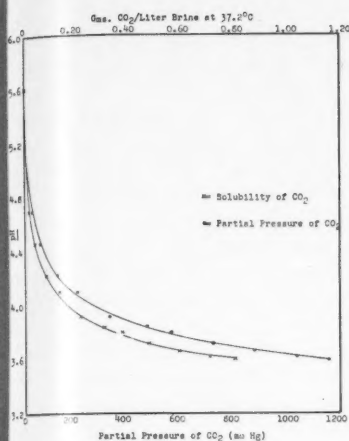


Figure 5—Recombination curve for sweet brine using carbon dioxide.

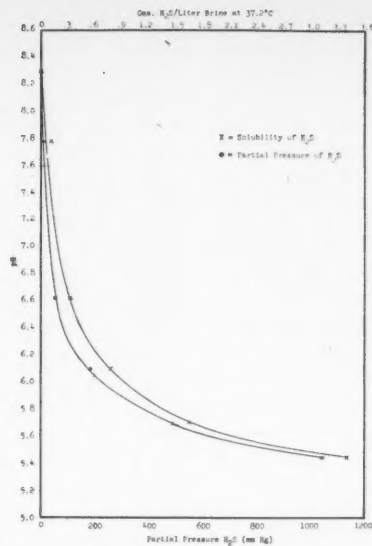


Figure 6—Recombination curve for sulfide brine using hydrogen sulfide.

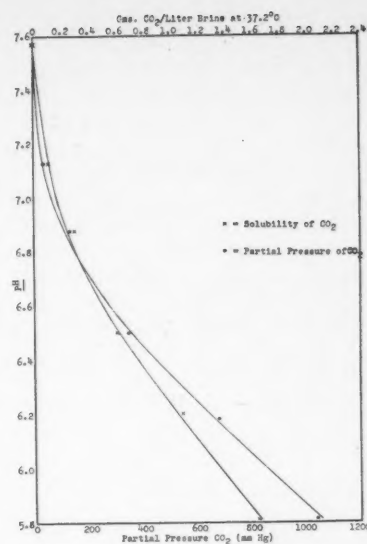


Figure 7—Recombination curve for sulfide brine using carbon dioxide.

mately equal decreases in pH. After each addition the brine was circulated until the manometer showed no change and the mercury level and pH then read. The values of pH and corresponding partial pressure of carbon dioxide were thus obtained. By knowing the amount of wet (with water vapor in the gas burette) carbon dioxide added it was possible to calculate the total amount of dry carbon dioxide introduced into the system. The calculation was done according to the gas law as below:

$$\text{weight dry CO}_2 = \frac{(V \text{ wet CO}_2) (P \text{ atmospheric} - P \text{ water vapor}) \times 44}{R \times T}$$

converting the gas constant R to the units employed the equation becomes:

$$W = \frac{V \times \frac{(\text{cc})}{(\text{gms})} \times \frac{(\text{mm Hg})}{P} \times 7.06 \times 10^{-4}}{T \text{ (Degrees Kelvin)}}$$

The weight of carbon dioxide in the vapor phase of the closed circulating system is similarly calculated for each partial pressure of the gas. The operating temperature of 37.2°C (99°F) has been incorporated in the constant:

$$\text{weight CO}_2 \text{ in vapor (gms)} = \frac{P \text{ CO}_2 \times V \text{ vapor space} \times 2.27 \times 10^{-6}}{(\text{mm Hg}) (\text{cc})}$$

The difference between the weight of dry carbon dioxide added and the carbon dioxide in the vapor space represents the acid gas dissolved in the brine. A solubility value for each partial pressure and the corresponding pH were thus obtained and the results plotted in Figure 5.

The brine, which had a total solids content of 200,000 ppm, gave a distribution coefficient with kerosene of 3.88:1 as calculated from the solubility data in Figure 5 and in the carbon dioxide-kerosene curve, Figure 3.

The well produced 176 barrels of brine per day and had an oil:brine ratio of 0.66:1. The daily gas production was 24,360 cubic feet at atmospheric pressure and 60 degrees F. The carbon dioxide content as measured by the absorption apparatus was 3.2 per cent, which converted to standard temperature and pressure (0 degrees C, 1 atmosphere) represents 737.4 cubic feet of carbon dioxide per day. The percentage of carbon dioxide was determined on a sample taken at the separator pressure of 1277 mm of mercury, which corresponds to a well head carbon dioxide partial pressure of 41 mm of mercury. From the recombination curve this value represents a well head pH of 4.66.

From the above data the well produces 1.464 gms of carbon dioxide for each liter of brine and for each 0.66 liters of oil. Taking into account the distribution coefficient, the bottom hole brine would thus contain

$$1.464 \left( \frac{1}{1 + (0.66 \times 3.88)} \right) = 0.411 \text{ gms of carbon dioxide}$$

which was dissolved at bottom hole pressure, but which was released at well head separator pressure. Adding to this the 0.027 gms of carbon dioxide which remains in solution at the well head pressure of 1277 mm of mercury gives a total bottom hole brine acid gas content of 0.438 gms which corresponds to a pH of 3.75, a reduction in pH of 0.91 unit from the top hole pH.

It should be emphasized that this calculated value is for a uniform temperature of 99 degrees F at well head and bottom hole locations. The acid gas solubility will decrease as temperature increases and if considerable variation between well head and bottom hole temperature occurs, the bottom hole pH may not be as low as calculated. From a corrosion rate standpoint, however, this increase in temperature would probably compensate for the rise in pH.

A corresponding test with West Texas sulfide

brine was conducted. In the case of this particular sulfide brine it was necessary to make two recombination runs using hydrogen sulfide for one and carbon dioxide for the other. This was due to the fact that the produced gas gave an analysis of 7.0 per cent hydrogen sulfide and 7.0 per cent carbon dioxide. Distribution coefficients for each gas were calculated; the values were not constant as in the case of the previously tested non-sulfide brines. The coefficients for the lower acid gas partial pressures showed the greatest variance, indicating that the sulfide water tested had a greater amount of alkalinity than the non-sulfide brines. This would cause the first acid gas added to be utilized in overcoming this alkalinity, thereby giving an apparent low distribution coefficient. After equilibrium was attained this

value began to level off. The data are shown in Tables II and III, and the solubility and partial pressure vs pH curves are plotted in Figures 6 and 7.

The well produced 46 barrels of brine/day with an oil:brine ratio of 0.565:1. The gas:oil ratio was 1985 cubic feet/barrel. On the basis of a separator pressure of 771 mm of mercury, the gas analyzed 7.0 per cent carbon dioxide and 7.0 per cent hydrogen sulfide. This corresponds to a well head partial pressure of 54 mm of mercury for each of the acid gases, which from the partial pressure-solubility curves in Figures 6 and 7 represents a well head pH of 6.50.

The acid gas produced, calculated to standard temperature and pressure, is 420 pounds of carbon dioxide/day and 325 pounds of hydrogen sulfide/day. This represents 26.0 gms of carbon dioxide and 20.2 gms of hydrogen sulfide/liter of brine produced, which are dissolved at bottom hole pressure but which are released at separator pressure. Using distribution coefficients of 1.72 and 1.10 respectively, 13.3 gms of carbon dioxide and 12.8 gms of hydrogen sulfide are dissolved in each liter of brine at bottom hole conditions. Both of these values are of such magnitude as to lie beyond the limits of the curves in Figures 6 and 7. Since the laboratory apparatus is limited to pressures of 1200 mm of mercury and less, it would be impossible to recombine the acid gases in anything approximating the bottom hole conditions. However, from an estimated extrapolation of the solubility curves, it should be safe to say that the bottom hole pH will be a maximum of 4 and probably considerably lower. This is a bottom hole pH at least 2.5 units lower than top hole pH. This would aid in accounting for the high corrosion rates obtained in some sulfide wells.

#### Effect of Velocity And Temperature On Corrosion Rate

Inasmuch as the majority of the work on the corrosion apparatus was carried out at a circulation rate of 500 cc/minute and at a temperature of 99 degrees F, it was decided to vary the rate and temperature and ascertain their effect on corrosion rate. Utilizing an iron nail anode and a copper foil cathode, a series of readings were taken at varying brine velocities and at different pH levels. Carbon dioxide was used to lower the pH. The results are entered in Table IV.

Results in this table indicate that the velocity has more effect on the corrosion rate as the pH is decreased.

Runs on the same brine at two different temperatures were also made. The pH was controlled in each run by varying the carbon dioxide partial pressure. In this case the velocity was maintained constant at 500 cc/minute. The first run was made at 99 degrees F and the second at 132 degrees F. The results appear in Table V.

Thus, a 33 degree F increase for this particular brine gave approximately double the corrosion rate.

The same sweet brine was later tested under sul-

TABLE II

Partial Pressure of H <sub>2</sub> S (mm Hg)	Solubility in Kerosene (gms/liter)	Solubility in Brine (gms/liter)	Distribution Coefficient
100	0.27	0.51	0.53
200	0.57	0.85	0.67
300	0.89	1.15	0.77
400	1.23	1.45	0.85
500	1.60	1.73	0.93
600	1.97	1.98	1.00
700	2.37	2.25	1.05
800	2.78	2.55	1.09
900	3.19	2.90	1.10
1000	3.62	3.28	1.10

TABLE III

Partial Pressure of CO <sub>2</sub> (mm Hg)	Solubility in Kerosene (gms/liter)	Solubility in Brine (gms/liter)	Distribution Coefficient
100	0.25	0.24	1.04
200	0.51	0.40	1.28
300	0.77	0.55	1.40
400	1.04	0.70	1.49
500	1.29	0.85	1.52
600	1.56	1.00	1.56
700	1.84	1.15	1.60
800	2.12	1.29	1.63
900	2.40	1.43	1.68
1000	2.70	1.57	1.72

TABLE IV

Velocity (cc/min)	Corrosion Voltage (mv) at Different pH Values		
	pH 6.43	pH 5.75	pH 4.70
0	0.30	0.70	0.77
100	0.32	1.00	1.20
200	0.34	1.17	1.32
300	0.36	1.27	1.42
400	0.37	1.50	1.50
500	0.38	1.63	1.57
600	0.40	1.73	1.77
700		1.83	2.10

TABLE V

pH	Corrosion Voltage (mv) at Different Temperatures	
	99° F	132° F
6.90	0.30	0.64
6.60	0.35	0.75
6.20	0.44	0.90
5.80	0.56	1.10
5.60	0.64	1.23
5.30	0.82	1.53

TABLE VI

Velocity (cc/min)	Corrosion Voltage (mv) at pH 6.10 and 99° F	
	(Decreasing Rate)	(Increasing Rate)
700	19.55	17.25
600	15.60	12.70
500	13.50	10.85
400	9.85	8.30
300	7.70	7.25
200	6.55	6.25
100	5.08	4.88
0	1.47	1.47

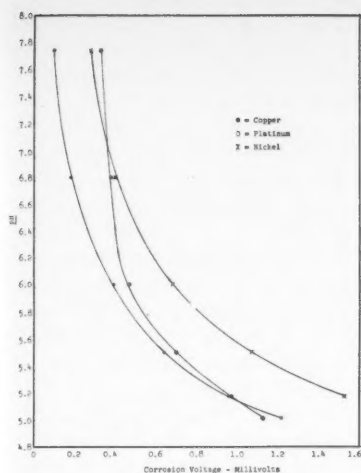


Figure 8—Corrosion rate in sweet brine using carbon dioxide with three different cathodic metals.

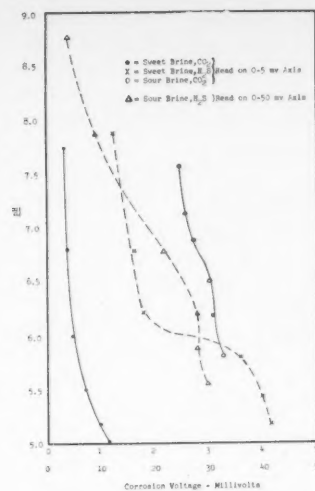


Figure 9—Corrosion rates of sweet and sour brines using carbon dioxide and hydrogen sulfide.

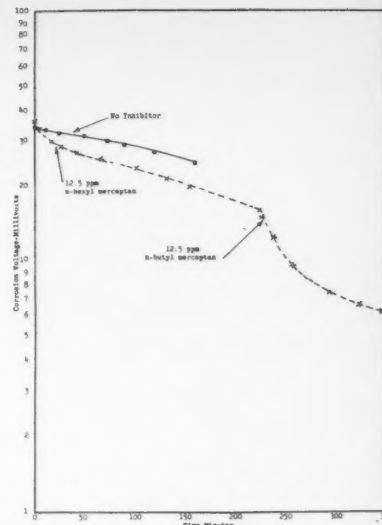


Figure 10—Effect of mercaptans on corrosion rate in sulfide brine.

sulfide conditions employing a nail anode and a cylindrical nickel sheet as a cathode. The effect of circulation rate and temperature was again recorded and the results appear in Tables VI, VII and VIII. It should be noted that a much higher corrosion rate was obtained with the sulfide gas using a nickel cathode than with carbon dioxide gas using a copper cathode. The circulation rate was decreased to zero and increased back to its original value to see the overall effect of the decreased velocity with time.

The drop off is apparently uniform and the corrosion rate is not lowered more than would normally be expected over a period of time. The elapsed time from the initial reading to the final reading was 5 hours and 15 minutes.

In the case of varying the brine velocity the effect is apparently one of changing the hydrogen over-voltage on the cathode. Electrode measurements on the potentials of both the anode and the cathode showed that the anode remained at approximately the same potential regardless of the velocity. The cathode, on the other hand, changed noticeably. The potentials were measured against a normal calomel electrode and the results are recorded in Table VII.

The temperature effect was measured at a constant pH of 7.60 on the same brine. The high pH was obtained after evacuation and before any acid gas had been added.

The corrosion rate increase due to temperature rises is apparently a matter of making ferrous ions more readily deposited in solution and of causing hydrogen to be more easily liberated at the cathode. The temperature therefore acts as a reaction accelerator.

#### Corrosion Rates of Sulfide and Non-Sulfide Brines

A number of sweet brines were tested as to carbon dioxide corrosion rate using the nail anode and copper cathode corrosion cell. As mentioned previously, the copper was not satisfactory for sulfide

tests because of the formation of copper sulfide. Therefore, it was necessary to substitute a nickel cathode for the copper in subsequent determinations. The nickel proved quite satisfactory under sweet and sour test conditions. However, to be more certain of having an inert cathode, the metal finally decided upon was platinum. The cell at present consists of a No. 10 common nail and a piece of sheet platinum (made from a crucible lid) rolled into a 1/2-inch diameter cylinder.

One of the sweet brines was tested under carbon dioxide conditions using each of the three cathodes. As a means of comparing the corrosion rates under these three conditions the data are entered in Table IX.

The rates are of the same order of magnitude and within the limits of experimental error can probably be considered comparable. The curves of pH vs. corrosion voltage for the three runs are plotted in Figure 8.

The same brine was also tested using hydrogen

Velocity (cc/min)
700
400
0

TABLE VII

Potential Against Calomel Cell @ pH 6.10
Cathode
.497
.549
.616
Anode
.608
.616
.630

Temperature (°F)
80
86
93
99

TABLE VIII

Corrosion Voltage (mv) @ pH 7.60
0.70
0.88
1.09
1.31

pH
7.74
6.80
6.00
5.50
5.18
5.02

TABLE IX

Corrosion Voltage (mv) With Various Cathodes
Copper
0.10
0.18
0.39
0.64
0.96
1.22
Nickel
0.28
0.40
0.68
1.07
1.53
Platinum
0.33
0.38
0.47
0.70
0.97
1.13



sulfide as the acid gas and platinum as the cathode. In each case the corrosion rate for equal pH values was three to six times higher with the sulfide gas than with carbon dioxide. It is also interesting to note that the brine always attained a higher pH value upon evacuation at the completion of a sulfide run than it did after a carbon dioxide run.

In each run, whether sulfide or non-sulfide, the potential of both the cathode and the anode was followed with the potentiometer. The potential of the nail anode showed little variation, but the cathodic voltage varied directly in proportion to the corrosion rate. As the cathode depolarized the corrosion rate increased; this was represented by an increased potential difference between the nail and the platinum. Similarly, as polarization took place and the corrosion rate declined the cathode potential approached the value of the nail.

A number of sour brines from West Texas were subsequently tested using both carbon dioxide and hydrogen sulfide. In each run the iron nail and platinum cylinder were used. The sour brines for the most part showed much higher corrosion rates than non-sulfide brines at the same pH values. Inasmuch as sulfide gas was injected into the sweet brines with much less corrosivity than in the sour brines, the difference may be due to the difference in dissolved sulfide concentrations in the brines. Credence is lent to this argument by the fact that evacuation of a sour brine after a sulfide run resulted in a sulfide residual of 400-600 ppm in the brine even though the pH ranged from 8.5 to 9.0. Apparently a number of the sulfide brines have a much higher alkalinity than the majority of the non-sulfide brines tested. This results in a much higher sulfide concentration being obtained in solution at pH values comparable to those of the sweet brines. This property also holds true to a lesser degree for tests on both types of brines with carbon dioxide gas.

The variance in corrosion rates at constant pH for two typical sweet and sour brines after injection with each acid gas is shown in Table X. In all runs the brine was circulated at 99 degrees F with a fluid velocity of 500 cc/minute. The corrosion runs for each of these brines are plotted in Figure 9.

From these data a logical explanation for the high corrosion rates in certain sour brines may be derived. In order for the pH value in the sour brine to be comparable to the sweet brine pH it is necessary to have from four to eight times the amount of acid gas in solution, whether it be carbon dioxide or hydrogen sulfide.

### Corrosion Inhibitors

After establishing the corrosivity of a number of

brines, the next step was an investigation of the corrosion inhibiting ability of a variety of different materials. Inasmuch as higher corrosion rates were obtained with sulfide brines, they were utilized for the majority of the basic studies.

Prior to testing any of the commercial inhibitors it was decided to approach the problem from the standpoint of natural inhibitors which may be present in oil well crudes. Some sour brines are known to contain sulfur compounds other than hydrogen sulfide and there is evidence that some of these compounds may be alkyl mercaptans and sulfides. Several reagent mercaptans were thus secured for purposes of evaluation of their effect on sulfide corrosion rate.

A 300 cc filtered sour brine sample was introduced into the corrosion apparatus and evacuated until a stable low corrosion voltage was obtained. Hydrogen sulfide gas was introduced into the brine until a high corrosion voltage of the order of 30-40 millivolts was obtained. Inasmuch as this value is not constant but rather shows a gradual decline over a period of time, it was decided to plot the corrosion voltage against time. Semi-logarithmic paper gave the nearest to a straight line function. Since the curves were found to be reproducible for the same brine it was then possible to use this as a standard with which the inhibitor treated brine could be compared.

After obtaining a voltage vs. time curve for a brine, the system was evacuated and sulfide gas recombined to restore the original high corrosion rate (in some cases the corrosion rate after completion of the no inhibitor run was sufficiently high to allow the inhibitor to be injected without evacuation and re-acidization). Because of the small volume of brine handled it is impractical to inject inhibitors to give a concentration of 50 ppm or less without first diluting. A 5 per cent solution of inhibitor was generally employed so that a 0.4 cc injection would result in a 50 ppm dosage. In cases where solvents other than water were employed no effect on corrosion rate due to solvent alone was apparent. The inhibitor solution was introduced into the brine by means of a 2 cc syringe equipped with a small hypodermic needle. The needle pierced a section of rubber tubing on the Sigmamotor pump suction side, thereby resulting in good distribution of the inhibitor.

Since the mercaptans and alkyl sulfides are not readily water soluble, methanol was used as the solvent. Methanol solutions containing 5 per cent of ethyl, n-propyl, n-butyl, tertiary butyl, n-hexyl, phenyl, and benzyl mercaptans were prepared. All but the phenyl derivative showed definite inhibitive properties at 12.5 ppm concentration. The curves for n-hexyl and n-butyl mercaptan are shown in Figure 10.

A number of commercial inhibitors have also been tested in the apparatus using both sulfide and non-sulfide brines. Only those compounds which are soluble, dispersible, or emulsifiable in the brine were injected. In cases where pro-

TABLE X

Brine and Acid Gas	pH After Evacuation	Part. Pressure of Acid Gas @ pH 5.80 (mm Hg)	Acid Gas in Sol. @ pH 5.80 (ppm)	Cor. Rate @ pH 5.80 (mv)	Cor. Rate @ pH 5.80 (ipy)
Sweet CO <sub>2</sub>	7.74	210	232*	0.57	0.007
Sweet H <sub>2</sub> S	7.88	260	634*	3.57	0.042
Sour CO <sub>2</sub>	7.57	1040	1710*	3.08	0.036
Sour H <sub>2</sub> S	8.77	625	2734	28.3	0.331

These 3 values do not include the amount of sulfides or carbonates remaining in solution as soluble salts after evacuation. The 4th entry in this column does include this figure, which was obtained by an iodimetric titration.

tection is afforded the inhibitors evidently work in a physical adsorptive manner rather than as chemically reactive agents. The effect shown by potentiometer readings was one of an increase in cathode potential which would be expected from a high hydrogen over-voltage. Several of the commercial inhibitors gave very good corrosion rate reduction in concentrations of 50 ppm and will be tested under field conditions in the near future.

#### Summary and Conclusions

A laboratory apparatus has been constructed for measuring the corrosion rates of oil well brines under oxygen-free conditions. The apparatus is capable of withstanding pressures up to about 25 psia. The corrosion index is the current output of a galvanic cell. The studies made have included tests to determine the pH effect of recombining into oil well brines the acid gases released to the atmosphere when they are produced from formation to atmospheric pressure. The data in this report show that reductions in pH of 0.91 to 2.5 pH units result from such recombinations. Additional unreported data show no pH reduction in some cases as the result of small quantities of acid gases being present in the fluid under formation conditions. Thus, whereas the top hole pH of an oil well brine may be in the range of  $\text{pH } 6.50 \pm 0.50$ , the bottom hole pH may range up to 2.5 pH units lower. Such reduction of pH to the acid condition can contribute greatly to the development of high subsurface corrosion rates.

Data obtained with the cell show that increasing temperature and velocity accelerated the corrosion rate. It is easy to show from the data obtained that the corrosion rate of an oil well brine at bottom hole pH and temperature can be six to ten times as great as at top hole conditions of pH and atmospheric temperature.

The apparatus is likewise applicable to the study of inhibitors and it has been found that alkyl mercaptans can act as inhibitors under sulfide conditions. These materials are known to be present in some sulfide fluids but their value as inhibitors in such cases has not been reported.

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#### DISCUSSION

**Question by Charles C. Nathan, The Texas Company, Bellaire, Texas:**

Were various mercaptans other than the butyl mercaptan evaluated as inhibitors? If so, what was the effect of the structure of the inhibitor molecule on its inhibition efficiency?

**Reply by J. A. Rowe, Jr.:**

Several aliphatic and aromatic mercaptans were tested and all gave results similar to those of the butyl mercaptan. The detailed results are to be published in the future.

**Discussion by L. C. Case, Gulf Oil Corp., Tulsa, Okla.:**

This apparatus and technique seem to provide an excellent means for determining the relative corrosive effect of the acid gases. Since this subject is one under much present discussion, and because there is considerable disagreement, I am sure that data on the separate and combined effects of  $\text{CO}_2$  and  $\text{H}_2\text{S}$  would be appreciated if available.

**Reply by J. A. Rowe, Jr.:**

The separate and combined effects of  $\text{CO}_2$  and  $\text{H}_2\text{S}$  have been studied and the data obtained will be a basis for future publication.

**Question by J. Sudbury, Continental Oil Co., Ponca City, Okla.:**

What is difference between a sweet and sour brine? (Other than  $\text{H}_2\text{S}$  content).

**Reply by J. A. Rowe, Jr.:**

Residual sulfides other than  $\text{H}_2\text{S}$ .

**Question by William F. Oxford, Jr., Sun Oil Co., Beaumont, Texas:**

Is there a definite correlation that bottom hole pH will be to the order of one or more units less than observed top hole pH?

**Reply by W. F. Rogers:**

No. In a well with little or no  $\text{CO}_2$  or  $\text{H}_2\text{S}$  in the well head separator gas, the pH reduction from top to bottom hole may be less than one unit. In an East Texas brine tested the pH reduction approximated zero. Other factors influencing the pH lowering are the distribution coefficient of the acid gas between the oil and brine and the gas:oil:brine ratio of the well.

# Designing for Corrosive Services \*

By F. A. PRANGE\*

**D**ESIGNING for corrosive services is more involved than merely selecting a material with good corrosion resistance. Processes can be changed to make them less corrosive, metals can be heat-treated to increase corrosion resistance and good inspection may allow the use of less corrosion-resistant and cheaper materials. This article is not intended to illustrate the design of an individual plant, nor to discuss corrosion test methods. Instead, this paper is intended to explore the basic philosophy of design and to examine inter-relationship between processes, corrosion of materials, fabrication and construction of equipment and physical properties required of the structures.

Unlike electrical design or mechanical design, there are few mathematical formulas to answer corrosion problems. It is not possible to set up a process, feed the dimensions and constants into a calculating machine and get the answer. In fact, most of the time all the variables cannot even be enumerated, much less evaluated. Though a new day seems to be dawning, as is evinced by the attendance at the meetings of the National Association of Corrosion Engineers, some plants are still being built with little more than hope about the extent of corrosion. Good design generally requires analytical thought and pilot plant work.

Pilot plant work necessary for proper design is more than putting samples into a beaker of the process fluid to obtain the weight loss. Instead, pilot plant work should concern the interdependence between process and materials of construction. Frequently it is cheaper to make process changes, perhaps even slight ones, than to use the expensive materials of superior corrosion resistance. Careful observations on pilot plant equipment can give a great deal of information difficult to obtain in other ways. Only from actual equipment can one determine the possibility of such types of attack of corrosion—erosion, blistering, dezincification, bimetallic corrosion and embrittlement. Table I enumerates the various types of corrosion that may occur. General thinning, the type of attack most often measured, is a valid measure of material requirements only when none of the other types of corrosion are serious. At least in the oil industry general thinning is the unusual mode of failure. Pilot plant tests with careful observation of the equipment and critical examination of the results can give a wealth of information—inexpensively too. The preliminary pilot plant ob-

## Abstract

This paper discusses in a general fashion the problems of designing for corrosive processes. Good design data, which is obtainable from the pilot plant data will insure more reliable operation of the full scale plant. Shutdown procedures and equipment inspection methods should be considered in the designs. In the choice of materials due consideration should be given to ease of fabrication and ability to withstand abuse. Failure analysis of the pilot plant and full scale equipment can do much to improve reliability and to reduce cost of construction.

servations will indicate further tests that should be made either in the direction of materials or of process changes to minimize corrosion.

There are three ways to control corrosion and most problems should be examined from all three viewpoints in order to arrive at the best solution. The control methods are these:

1. Change the process to make it less corrosive.
2. Use more corrosion-resistant materials.
3. Put a barrier between the corrosive fluid and the load-carrying base metal.

Within a given problem all three methods may be applicable, so that deciding on the various steps of a process and making the choice of materials of construction is much like solving a series of simultaneous equations. The answer would always have to be proved by economics.

A few examples of the first control method may be of interest. Liquid-phase butane isomerization units experienced corrosion rates on steel up to 10 inches per year. Hastelloy B lining material was adequately corrosion-resistant, but it cost a great deal and was difficult to apply to the steel vessels. An excellent solution to the problem was to change the process to a vapor-phase cycle in which steel corrodes at the rate of only a few thousands of an inch a year. Another example is the exclusion of chlorides from a system in order to avoid stress corrosion cracking

TABLE I—Types of Corrosion

1. Stress corrosion cracking, season cracking.
2. Stress corrosion.
3. Bimetallic corrosion, galvanic corrosion, electrolytic corrosion.
4. Graphitic corrosion.
5. Dezincification, denickelization, dealuminization.
6. Hydrogen disintegration ( $H_2$  at elevated temperature).
7. Blistering.
8. Embrittlement.
9. Intergranular corrosion.
10. Corrosion fatigue.
11. Pitting.
12. Alloying—carburization, nitriding, amalgamation, sulfidization.
13. Oxidation.
14. Scaling.
15. General thinning.

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of austenitic stainless steels. Recognition of the type of corrosion and critical diagnosis of the corrosion will suggest possible process changes. Of course, it may be cheaper to use higher priced materials or continue to suffer the corrosion than to change the process. In some cases, high corrosion rates may be tolerable from an economic standpoint when all factors such as costs of alternates, desired life of equipment and availability are considered.

The use of corrosion resistant materials is the second method of corrosion control. Much of the time in process industry work this method is not nearly as applicable as the first. Nevertheless, except for the very specialized fields, it is an integral part of the corrosion engineer's tool kit. Table II is a list of alloys that may be used to define rather completely the corrosive characteristics of a system and point out materials that deserve initial consideration. Of course, it is not usually necessary to test all of these when some are clearly contraindicated. The phenomena experienced on these alloys will in turn suggest some that should be used in final tests or in the design. As an example, intergranular corrosion of Type 304 stainless suggests that Type 321 or 347 stainless or low-carbon 304 stainless should be used.

The third method, somewhat similar to the second, is to place a barrier between the corrosive fluid and the load-carrying base metal. Such barriers may be lead or stainless steel linings, porcelain coatings, rubber sheet, or paint. Several difficulties are inherent in the use of these. Ordinarily it is not easy to get an acceptable bond between the base metal and the barrier material. Neither it is easy to avoid communication between the inside of the envelope and the exterior. Pinholes, slag pockets and cracks are common. Very thin films, such as paint film, have application only when the fluid is but slightly corrosive. They cannot be used to protect a steel shell for storing a material like 15 percent uninhibited hydrochloric acid. However, they are frequently used when it is desirable to minimize contamination of the product contained in the tank. Thus, these thin films might be used to prevent milk picking up metallic salts causing bad flavor. In evaluating thin films, it should be remembered that the resistance properties of the film tells us little about the pinholes and permeability which are almost universally present in commercial-sized equipment.

Unfortunately, resistance to the process fluid is not the only dimension to be considered in selecting materials. Cost per pound seems basic. Very often though, the fabrication is more costly than the material. As an example, some phenolic paints cost less than \$2 per pound, but by the time they are applied they may cost up to \$100 per pound. The ability to be fabricated readily is of tremendous concern. Fabrication properties go back to properties but remotely connected with corrosion resistance. Nevertheless, they govern the majority of designs.

Modern design relies a great deal on welded structures. Carbon steel is welded with such ease that the question of weldability of other materials is often dismissed without a thought. Carbon steel can

be welded in any position; it is not particularly hot short; welds in it are sound and dense; and the welds have strength and ductility equivalent to the base metal. Very few other metals and alloys have all of these desirable characteristics. Many of the highly corrosion resistant materials are welded only with great difficulty.

Physical properties also need attention. First, there must be adequate tensile strength to withstand the loads imposed. Elementary indeed, until the ramifications of the joining method are considered! How can two pieces of porcelain be joined to give a leak-free joint having no significant loss in strength? How can high strength aluminum be welded without a depreciation of the tensile strength? How can Hastelloy B be welded without extreme loss of ductility? So it goes through the whole roster of materials.

Though ductility requirements are not reduced to numerical quantities, ductility is an important property. There are many millions of pressure vessels in use that have no ductility, but these pop bottles are not nearly so large and complicated as plant vessels, nor does a single failure of them present the same degree of hazard. In a plant, glass can be used for pressure-containing equipment only if very strenuous efforts are made to see that the environment does not demand any plasticity. Generally, though, we ask that the constructional material and the finished unit be capable of deforming to take care of the loading not ordinarily calculated. The ductility required is more nearly the notched ductility (such as measured by notched bend tests or notched impact tests) rather than the ductility measured in the conventional tensile tests.

In much of the chemical and refinery work, ability to resist fire damage is a very important property. This is largely a function of the tensile strength and the short-time rupture strength at elevated temperatures. Creep—or cold flow—in the absence of fire is also neglected. Plastics at room temperatures, aluminum and copper alloys at temperatures above 200 F and steel above about 800 F gradually deform under load. In order to do a good job of design, it is necessary to know the stress-time-temperature-elongation characteristics of the material. It is a pronounced shortcoming of aluminum and plastics that such data are not readily available for them.

Several other points also receive attention in the selection of materials. These are the ability to resist mechanical damage during clean-out and shutdown, the ability to resist thermal shock and the ability to be repaired easily in the field. This last point is important in large scale equipment since repairs become costly and shutdowns prolonged when ready means of field repair are not available.

Table II reflects these various points in grouping the materials under "A," "B," or "C." The first group includes those commonly used in commercial equipment and which are readily fabricated. Group "B" includes those materials which can be fabricated into various parts but which are somewhat difficult to work or are expensive in first cost. Group "C" includes those applicable only with considerable

difficulty or at high cost. In grouping these materials, it was assumed that the process pressure or the process temperature was above atmospheric. It should be kept in mind that much corrosion resistant material is used to protect the product from contamination—not because a less resistant material would fail too quickly.

In designing equipment to be made from the various materials, one should keep in mind the possibility of bimetallic corrosion, corrosion-erosion, stress corrosion cracking, etc. However, most of the time if pilot plant work has been thorough enough, the degree of caution required will be known. Completely guarding against such types of corrosion as bimetallic is ridiculous. It is almost impossible to make equipment out of only one material. Valves and pumps must have special trim and instruments must have corrosion resistant working parts. Many writers warn against ever coupling dissimilar materials. Yet how many of the writers are putting in all-steel valves in their house to replace the brass trimmed valves which are performing satisfactorily?

Shutdown procedure affects equipment design to a marked degree. Serious corrosion often occurs during shutdown because corrosive agents are formed that never occur in the process fluid. For example, air may get into the system and cause pitting of the copper alloys. In alkylation units and isomerization plants, aqueous acid is formed when water is used to wash out the equipment. These plants must be built to provide means for getting water out of the unit quickly. Siphon drains may cause corrosion because they do not allow complete drainage vessels. They have another disadvantage in that they frequently corrode off, so that the vessel cannot be drained. So, to insure complete drainage it is highly desirable to tilt horizontal vessels so water may be drained off one end or the other. Too often a sag in a horizontal vessel allows water to stand in the bottom. Another cause of corrosion during shutdowns is condensation of corrosive moisture. Besides the pitting and general corrosion which may occur, it has been known to damage sensitized 18-8 stainless.

When painting is necessary to protect against atmospheric corrosion, good surface preparation and the use of good primer are worthwhile. Equipment located so it is subjected to cooling tower fog and spray can make paint maintenance very costly. Similarly, it is necessary to avoid highly corrosive areas when burying pipe.

While corrosion products are frequently thought of as being soluble in the process fluid, quite fre-

quently they are not. It is necessary to provide some means for getting the scale and solids out of the stream so they will not plug valves, instruments and pump intakes.

Field repairs and modifications deserve some attention, since welding in new nozzles is done so frequently. Shell thickness should be such that code stress relieving will not be required when patches, nozzles, etc., are welded on. Only in a very few cases is the value of the stress-relieving treatment without question. The main benefit of this stress-relieving treatment is in obtaining better ductility. When choice of material or welding procedure achieves this, then stress-relieving treatment is mere fulfillment of a written code. However, there are cases when stress relieving is unquestionably necessary. Stress corrosion cracking, such as occurs in tanks handling caustic or in tanks used in amine gas treating plants, demands high temperature stress relief. This stress relieving must be more thorough than that demanded by the code. Not even ladder lugs can be welded on the vessel after stress-relieving treatment if the vessel is to be free of points capable of cracking.

Welding processes may affect corrosion. Automatic submerged-arc welds in carbon steel seem to be more subject to attack than manual welds when exposed to weak acids. In some poor automatic welds, the center line—corresponding to the pipe in an ingot of steel—may be rather spongy and especially susceptible to attack. For this reason, in many corrosive services manual welding of the parts exposed to process fluid will be worthwhile.

Proper selection of pipe is important. Pipe made from rimmed steel—the steel commonly used in lap-weld, butt-weld and continuous-weld pipe—is sometimes subject to extreme pitting in addition to corrosion at the weld seam, particularly when exposed to acidic environment. For these services, seamless pipe, which is made of killed steel, is the preferred material. From the standpoint of corrosion, there is little advantage in the use of good quality pipe in the handling of such materials as aerated neutral water. The kind of steel seems to have little effect in determining the corrosion rate in this medium.

There is also a very great difference in physical properties among the various grades of pipe. This difference is manifest in the ability to withstand plastic deformation. The property of good ductility is required when pipe is accidentally bent, when something falls on it, when men lean against it, when the fluid in the pipe freezes, or when the line is subjected to overpressuring. Frequently the weld area of butt-weld and continuous-weld pipe is extremely brittle and notch sensitive. There is very little butt-weld or continuous-weld pipe that will withstand the crush test with the weld area in bending. Lap-weld pipe is generally somewhat better, but the Bessemer steel commonly used for it is also somewhat notch sensitive. From the stand-

TABLE II—Desirable Materials for Corrosion Testing

GROUP A	GROUP B	GROUP C
Carbon Steel	Type 347 or Type 321 Stainless	Titanium
Type 304 Stainless (18-8)	Type 430 Stainless (16 Cr)	Silver
Type 410 Stainless (12 Cr)	Type 446 Stainless (27 Cr)	Tantalum
Type 317 Stainless (16-13-3)	Hastelloy B	Gold
Inhibited Admiralty	Hastelloy C	Platinum
Cupro-Nickel	Copper	Glass Linings
Silicon Bronze	Lead	Thin Organic Coatings
Aluminum Bronze	Inconel	Porcelain
Monel	Nickel	Graphite
Steam Bronze (85-5-5-5)	Polyvinylidene Chloride	Carbon
Grey Cast Iron	Polyvinyl Chloride	Sulfur
Type 38 Aluminum	Appropriate Rubbers	14% Si Iron
		High Alloy Stainless Steels

point of ability to withstand plastic deformation, quality is generally in the following order:

Seamless pipe made of open-hearth or electric-furnace steel.

Seamless pipe made of deoxidized Bessemer steel.

Electric-weld pipe that has been expanded to final size.

Plain electric-weld pipe.

Lap-weld pipe.

Butt-weld pipe and continuous-weld pipe.

The last named materials can be fairly good if made of open-hearth steel. Such better quality steel is apparent by its ability to withstand a crush test with the weld at 90 degrees or 0 degree to the direction of the applied force. As commonly used, grade designations are but slightly related to the quality. It is extremely poor seamless pipe that is not better than the best continuous weld pipe made of rimmed Bessemer steel, even though the specifications for the latter seemingly call for better grade material.

Materials with a high degree of corrosion resistance are not always necessary. Corrosion can be tolerated if no hazard or great inconvenience is occasioned by failure. Test hole drilling, which is frequently used in refineries, is one means of detecting corrosion before it becomes serious. Several new

instruments in common use allow carbon steel to be used where it formerly was not practical. These instruments allow the wall thickness of vessels and piping to be checked while in service or at least without disassembly of the equipment. One of these instruments depends on the use of supersonic vibration while the other utilizes gamma ray.

Designing for corrosive services goes a little further. Even after a plant is running, careful designing is still necessary. Failures should be examined closely. Some types of failure, like embrittlement, blistering and corrosion fatigue, may require a long period of time before becoming evident (in hydrofluoric acid alkylation, blistering was not found in the pilot plant equipment). Further, it is necessary to watch constantly for signs of distress; and it is especially important to check minor failures because they may be signs of things to come. In one case, a few slight leaks under unusual circumstances was the basis for a Magnaflux inspection. This inspection disclosed very severe stress-corrosion cracking. A study of the process variables, as well as a laboratory metallurgical examination, made it possible to prescribe stress-relieving and structural design changes, which, together with process changes, effectively minimize the failures. Materials do not fail without a good cause, and it is desirable to know the cause! The value of good failure analysis can hardly be over-estimated.

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# Statistics—A Useful Tool For the Examination of Corrosion Data\*

By CHARLES F. LEWIS

**T**HE IDEA "you can prove anything with statistics" must be dispelled. Nothing could be farther from the truth. Statistics, that is the use of statistical methods, cannot in the nature of things, yield proof. It does give a certain type of information that becomes valuable when combined with evidence from other sources. It helps to clarify the picture at hand and to allow a much sounder judgment. It is another tool in the engineers' kit bag.

Statistics tend to remove the human bias. Two equally competent people may draw almost diametrically opposite opinions from exactly the same set of data. There is a tendency to use data to support preconceived opinions. It is this human weakness that is minimized by statistical analysis. That is because statistical inference is always associated with a probability level and personal judgment is colored by credulity. A person will have more or less confidence in the findings depending upon his reaction to a stated probability level. When one wants to impress someone with the certainty of an event occurring he often uses the expression "9 times out of 10," or to give added emphasis, "99 times out of 100." This is an instinctive statement of the fact the event is expected but, at the same time, an admission that there is a certain chance it will not occur. The statistician does exactly the same thing except in different, and perhaps a bit more precise, language. He states in mathematical terms that, under the conditions given him, the event has a certain probability of occurring. In this article this concept is developed somewhat more fully and a graphical technique for analyzing one type of data that arises quite frequently is offered.

Argument is continued to the situation in which the observer has made repeated determinations in an experiment in an effort to obtain the best numerical value of some constant—the corrosion rate of a certain material under a certain specific set of conditions perhaps. Concurrent with arriving at an estimate of the most probable value of the constant the means to answer several other questions which often arise will be developed. Such as:

1. What degree of confidence can be placed in the accuracy of the estimate?
2. How much scatter can be expected if the experiment is repeated?
3. If the experiment is repeated how many readings should be taken in order to assure a high probability that the estimated value is within plus or minus k% of its true value?

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## Abstract

"All Empirical data are probable only."

A group of observations taken to establish the value of an empirical constant must be considered as a sample of an infinitely large population, or universe, of possible readings. By the application of appropriate statistical methods to the sample one may arrive at certain conclusions regarding the entire universe. The purpose of this paper is to discuss some basic concepts of statistical thinking, and to offer a graphical solution to the problem of estimating universe values from the sample values.

The data are prepared and plotted on special graph paper against a probability scale. From the plot are taken the most probable value of the constant sought; and the standard deviation. This latter is the slope of the plotted line, and is the key to further prediction from the data such as the confidence limits of the estimated average; a numerical expression of the precision of the test method used; and a means of comparing this method with another as to accuracy and precision. It also furnishes the answer to the question: "In the future how many readings should I take in order to have a high assurance (say of the order of 90 to 95 percent) that my estimated average will be within plus or minus 1 percent its true value."

"All empirical data are probable only." This statement is completely axiomatic. No matter how carefully an experiment is conducted, or set up, there is always present a number of variables over which there is no control or which would be uneconomical to control. A good many other variables are present that cannot be taken into account even if they could be identified, such as: minute local changes in structure and analysis of the material being tested; instantaneous and local changes in temperature, pressure and their effects on apparatus; constantly changing concentration and movement of a solution at pinpoint positions; stray currents; error in the reading of instruments; even the eyesight, digestion and mood of the observer. These, and a host of other factors combine to produce the inevitable scatter in the data. This multitude of unknown forces are constantly shifting in magnitude and in direction. At any given

instant they tend to cancel out each other. Thus, one time the reading will be a shade high and another time a mite low. Over a number of readings the net effect will approach zero. If the instant when the total was actually zero could be known an exact value of the constant could be set, but of course this cannot be done. In an effort to achieve accuracy then, a number of readings all under essentially the same conditions are taken and the average of these is used as the value of the constant sought. But think a moment! If the average of ten readings is used what happens when the eleventh is thrown in? A hundred readings can be averaged and the hundred and first would change the average a little bit. The average of  $N$  readings will nearly always be slightly different from the average of  $N$  plus 1 readings. But where can one stop? This is usually determined by economic factors. The exact or true value of the constant will never be known until  $N$  equals infinity, which, of course, is impossible.

What can be done, however, is to use a statistical approach based on the premise that the data at hand is a sample taken from the infinite population, or universe, of readings possible in the particular setup. Then, from data of the sample, a value can be derived which is the same as that which would have been established had a very large, or practically infinite, number of readings been made. This procedure would establish also a bracket within which, with a chosen probability, a true value is apt to lie.

Note carefully the wording: "From the data at hand the value of the constant is estimated to be about  $C$ . The probability is .90 that if one were able to take a very large number of readings the average of these would lie between  $A$  and  $B$ ." Saying it in another, and perhaps better way, "The value of the constant is estimated to be  $C$  with about 90 percent assurance (probability equals .90) that the estimate is not in error by more than plus or minus  $k$  percent.

This sort of answer is readily understandable and conveys a considerably clearer picture and also, which is more important, it offers an idea of the limitations of knowledge. The prediction has been made, and a hedge has been built against the very rare case when all variables act, by pure chance, in the same direction at their maximum magnitude to yield a completely freakish result.

### The Frequency Distribution

In any well controlled experiment usually it may be assumed that each individual observation is an independent estimate of the universe average or true value of the constant to be determined. The discrepancies noted in the individual readings reasonably may be laid to random variation of chance causes and should follow the mathematical laws of pure chance. If observed values are plotted against the frequency with which each value is observed it will be found that most values tend to cluster close together near the average with only an occasional reading at some distance away. If there are a large number of data and the curve is smoothed through the plotted points it will define the frequency distribution of the universe from which the data are drawn. Very often

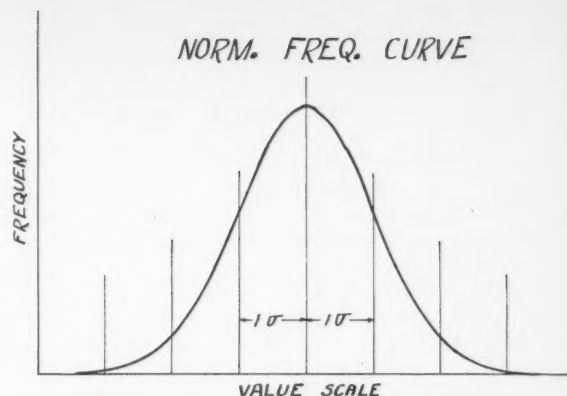


Figure 1—The normal frequency distribution curve showing the relative areas defined by integral numbers of sigma units. This is the ideal mathematically true curve of  $y = ae^{-bx^2}$ .

this will form a very familiar bell shaped pattern known variously as the normal frequency distribution curve, the Gaussian curve of error, or the Laplacian curve. Its properties are well known and from the basis of the analysis. (see Figure 1) Mathematically the curve has the form:

$$y = ae^{-bx^2}$$

The constants of the equation determine the position of the center line of the curve on the horizontal scale and the rate at which the tails approach zero frequency. Note it is symmetrical about its center line and extends from minus infinity to plus infinity. Note also that there is a point of inflection on each flank where the curvature changes from concave to convex. It so happens that the position of these points of inflection with respect to the X-axis bear a definite relationship to the total area under the curve regardless of the value of the constants of the equation.

The distance out to this point of inflection from the center forms the key to the statistical analysis of the data. It is called the Standard Deviation and has the same dimensional units as the data from which it is derived. It is usually given the symbol of the Greek letter sigma ( $\sigma$ ). The area encompassed by the two points of inflection, that is the mean plus and minus one sigma, will always be about  $\frac{2}{3}$  of the total area under the curve regardless of the numerical size of sigma. Two sigmas on each side will contain some 95 percent, and three sigmas on each side will have better than 99 percent of the total area (and hence 99 percent of the universe data) between them.\* Thus if reasonable estimates of the mean and the standard deviations can be obtained, many things can be done. For instance, about one time in three an individual observation can be expected to deviate from the mean by more than one sigma; only about one time in 20 should one be farther off than two sigma units and practically never would a chance deviation of more than three sigmas be expected. Inverting this thought, a reading was observed three or more sigmas off the average, the probability is very high indeed that it did not occur by pure chance. Some new variable must have entered the system to create a new situa-

\* The exact figures taken from a table of the probability integral are 68.27%, 95.45% and 99.63% respectively.

tion. This concept of probability of occurrence then forms the basis of statistical thinking. One calculates the probability that a certain event could happen by chance and if this probability is quite low (1 percent and 5 percent are common criteria) then it is said it did not happen by chance. It is theoretically possible to throw a hundred straight passes in a crap game, but the chances of doing so are so remote—that is, the odds against it are so high—that if it was seen one would instinctively attribute it to something besides the luck of the thrower.

In statistical jargon, the hypothesis that the occurrence was a chance happening would be rejected and an assignable cause of the extreme variate would be sought. Consider then, a method of estimating from known data the population average and standard deviation. Experimentation is expensive and to gather sufficient readings to define the frequency curve precisely enough to get estimates in that manner would be completely prohibitive. Fortunately there is a technique available that produces rather good estimates with relatively few data. The trick lies in appropriately arranging the data; making certain simple calculations using the observed frequencies; and plotting on special graph paper having a probability scale. Usually fairly good estimates can be obtained from groups of the order of ten or a dozen.

From an operational standpoint the method can

**TABLE I**  
Erosion-Corrosion of 30% Cupro-Nickel With and Without Iron Addition in Synthetic Sea Water. pH of 8.2 50° C.

Test No.	Iron Content Percent	Highly Erosive	Tubulent	Stagnant
1.....	.12	60	10 11	....
2.....	.12	10	4 3	1
3.....	.12	39	3 3	0.3
4.....	.12	17	2 2	1
5.....	.12	49	4 4	1
6.....	.59	29	6 5	....
7.....	.59	9	5 5	2
8.....	.59	4	0.3 1	0.6
9.....	.59	5	2 1	0.4
10.....	.59	11	2 2	1

**TABLE II**  
Corrosion Rate of Iron-Free Material Tested Under Highly Erosive Conditions

Work Table for Preparation of the Data for Plotting on Probability Paper

Units mils per Yr.	f	cum f	cum Fraction	cum Percent
10.....	1	1	1/10	10
17.....	1	2	2/10	30
39.....	1	3	3/10	50
49.....	1	4	4/10	70
60.....	1	5	5/10	90

From the plot  $\bar{X} = 35$   $\sigma^2 = 21.1$   $n = 5$ . It is very likely (prob. = .90) that  $\bar{X}$  is not in error more than  $\pm 15.5$  mils (44%).

**TABLE III**  
Corrosion Rate of .59% Fe Material Under the Same Conditions  
Work Table for Preparation of the Data for Plotting

Units mils per Yr.	f	cum f	cum Fraction	cum Percent
4.....	1	1	1/5	10
5.....	1	2	2/5	30
9.....	1	3	3/5	50
11.....	1	4	4/5	70
29.....	1	5	5/5	90

best be shown by going through an example in some detail. The discussion will cover preparation of the data, the plotting and the interpretation of the plotted data. Typical is an article which appeared recently in the magazine CORROSION, dealing with the effects of erosion and turbulence on the corrosion rate of two materials. A standardized test method was devised and the results given as penetration rate in mils per year. The following table is taken from the article. (Table I.)

A single test run consisted of placing in the apparatus four specimens, presumably of identical materials. One of these was subjected to a highly erosive condition in addition to the corrosive atmosphere. Two were given some degree of turbulence, yielding duplicate results, and the fourth was held motionless or stagnant in the corrosive media. The two materials differ only in iron content—.12 percent Fe which the author called iron-free and one containing .59 percent Fe. The author did not state whether the two omissions in the stagnant column indicated a corrosive rate of nil or whether the data were considered valueless for some reason and hence not recorded.

In the interest of brevity and for the purpose of this paper only the data in the column headed "highly erosive" will be considered. Here it is desired to demonstrate any real effects of the presence of iron on corrosion rate and to try to estimate the magnitude of the difference if it does exist. Also to be derived is an expression for expected scatter and a quantitative idea of the confidence that may be placed on the estimated average corrosion rate of each material.

The data, arranged for probability plotting are shown in Tables II and III along with the necessary computations. In general this would be a work sheet and would not normally be included in a formal paper. The minimum amount of information published should include  $\bar{X}$  (estimated population average),  $\sigma$  (estimated standard deviation of the population) and  $n$ , the size of the sample or in this case the number of data used.

### Preparation of the Data

Note that the data are arranged in ascending order of magnitude. This, in all probability, will not be the order in which it was originally recorded. Do not destroy the original order as there are other statistical tests that one may wish to make later in which the order of occurrence is important. From this point on, in a statistical sense, it makes no difference what the figures represent. They may be the corrosion rate of a material, the burning life of an electric light bulb or the errors per day in a billing department. The only stipulation is that they must be randomly chosen—that is, no single individual has a better chance of being chosen than another—and that they are expected, from an engineering standpoint, to have the same value.

A few comments on each column are in order:

1. Column 1 is of course the original data arranged in order of increasing size—usually marked X.
2. Column 2 (marked f) is the frequency with which each particular value of corrosion rate was observed. In this case there was only one reading at each level.
3. The next column (marked cum f) is the cumulated



frequency of the units in ascending order. Each entry is the sum of all frequencies up to and including that value—the total number of specimens showing that corrosion rate or less. The last entry in this column will equal  $n$ —the total number of observations. Integrating under the frequency curve from left to right is effected.

4. The column marked "cumulative fraction" is computed from the cum  $f$  column by adding each entry to its preceding entry and dividing by  $2n$ . This is called mid-point plotting.
5. The last column is merely the fraction column expressed as a percentage.

Now, in considerably less time than it takes to tell about it, the data are arranged in proper form for plotting on probability paper. This method of computing is simple, quick and easy and requires nothing but simple arithmetic.

### Plotting the Data

The data are now plotted on a special graph paper known as arithmetic probability paper.\* On this paper one axis is ruled proportional to the cumulated area from left to right under a normal distribution curve. Note that the scale extends from near zero at one end to nearly 100 percent at the other. Fifty percent, of course, is in the center of the scale, indicating that half the area is to the left and half to the right. Plotted then is the numerical value of the data against the cumulated percent as shown in column 5. A curve smoothed through the points thus plotted will define the parent distribution. A straight line plot indicates that the data came from a normally distributed population. A curved line would indicate a skewed distribution or possibly the existence of a limiting condition. This need be no bother, for expectancy can be read directly off the curve as one does any other empirical data.

The two parameters to be taken from the plot are the average and the standard deviation. The population average will be the value at the intersection of the 50 percent ordinate of the plot and the standard deviation will be the slope of the curve.

### Interpretation of the Data

The data of Tables II and III are plotted as a scattergram in Figure 2. Several things are to be noted. The data for the iron-free material forms a well defined straight line and can be said to be statistically homogeneous. The .59 percent Fe material however would form a good straight line if it were not for the last point at the value of 29. It could be argued that this should be included to form a smooth line concave upward but a squint test\*\* will show that this is hardly the case. The point here, apparently does not belong in the population—a maverick. It can be assumed that it was subject to some variable condition that was not present in the other four determinations. It is rather like weighing oneself several times, then pocketing a weight and weighing again including the last reading in the total data. So, reject this extreme value and recalculate the remaining data. This is shown in Table IV and the completed pair of curves from which a further deduction

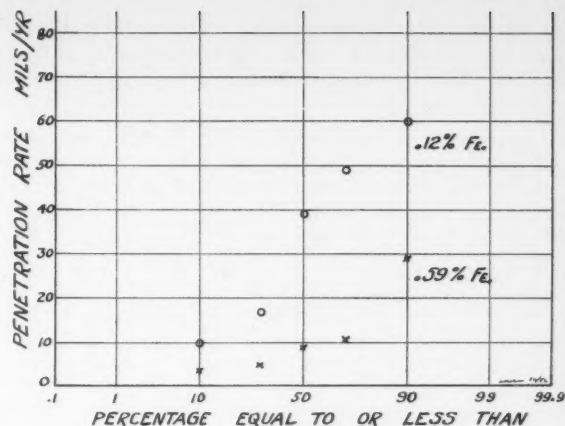


Figure 2—Scattergram of all of the data plotted on probability paper to show the presence of an extreme, highly improbable reading.

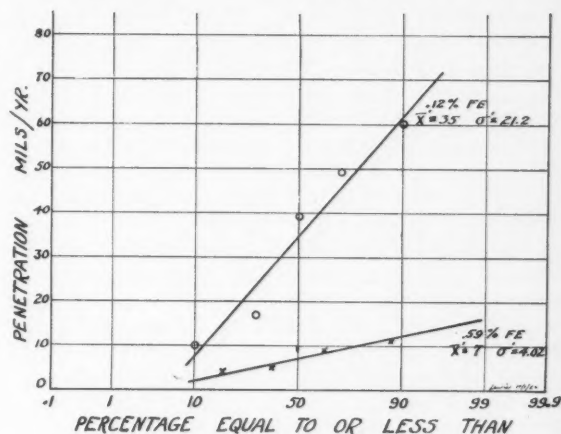


Figure 3—Final plot on probability paper of the accepted data. The universe average is the value at the 50 per cent intercept and the standard deviation is the slope of the plotted line.

will be made is shown in Figure 3. Note that the remaining data thus lie in an almost too perfect line. Reading from the plot, if these experiments were to be repeated a large number of times it would be expected material free of iron would yield an average penetration value of about 35 mils per year. But by adding about .52 percent iron this could be expected to diminish to about 7 mils per year. A few (1 or 2 percent) of the iron-free specimens may be expected to show as high as 80 or more mils per year penetration, while in those containing iron it would be rare indeed, perhaps one time in a thousand, if an indi-

TABLE IV  
Corrosion Rate of .59% Fe Material Under the Same Conditions  
With the Extreme Variate Excluded

Units mils per Yr.	$f$	cum $f$	cum Fraction	cum Percent
4.....	1	1	$\frac{1}{4}$	12.5
5.....	1	2	$\frac{2}{4}$	37.5
9.....	1	3	$\frac{3}{4}$	62.5
11.....	1	4	$\frac{4}{4}$	87.5

From the plot  $\bar{X} = 7$   $\sigma = 4.02$   $n = 4$ . It is very likely (prob. = .90) that  $\bar{X}$  is not in error more than  $\pm 3.3$  mils (47%).

\* The form shown is Technichart No. T327. Several companies offer this paper and it is available at most engineering and drafting supply stores. It is also made with a log scale vs. probability scale.

\*\* This is sometimes rounded off at 5/3.

vidual specimen were to show more than about 20 mils. This justifies the dropping of the extreme variate. This will be justified further after obtaining the standard deviation.

The slope of the plotted line, expressed in the same units as the data, is the estimated standard deviation. The value of sigma is easiest found by noting that the horizontal distance between the 10 percent and 90 percent ordinates on the probability scale is 2.563 sigmas in length—the mean plus and minus 1.28 sigmas. The slope is thus calculated by taking the difference of the vertical intercepts at these percentages and dividing by 2.563. In the case of the iron-free material in Figure 3 we have

$$\sigma' = \frac{62 - 7.7}{2.563} = 21.2 \text{ mils}$$

That for the revised iron-containing data is 4.02 mils indicating that not only is the average expected corrosion rate much less when iron is present but the measurements will be much more uniform from specimen to specimen. For instance, of the iron-free material about 90 percent (5 percent off each end) of the individual specimens will show between 3 and 70 mils penetration—a rather large spread—whereas the material containing iron can be expected to have most individual tests (90 percent) between 1 and 14 mils penetration. Note that this latter further justifies the dropping of the one value of 29 mils. As a matter of fact, on this particular curve from the mean of 7 out to value of 29 is 22 mils, which when divided by its standard deviation (4.02) indicates a deviation of some  $5\frac{1}{2}$  sigma units. Such a deviation could be expected to occur by chance alone about one time in several million. Hence the probability of finding one in a single sample of five is so remote that we reject the reading as containing variables not present in others. It simply cannot belong to the same family!

### Confidence Limits or Limits of Uncertainty

If several samples of a given size are drawn from a normal distribution, the sample averages will themselves form a normal distribution having the same general average as the population from which they were drawn but they will have much less scatter. The standard deviation of averages is directly proportional to the scatter of the individuals of the parent population and inversely proportional to the square root of the group size.

$$\sigma_{\bar{x}} = \frac{\sigma'}{\sqrt{n}}$$

This is called the standard error of the mean and it has the same significance as the standard deviation of individuals. The standard error is thus calculated from the sigma prime off the plot. It offers evidence

of how close the estimated population average can be trusted. For instance 9 out of 10 sample averages will lie within the bracket plus and minus 1.645 standard errors.\* Say then that when the probability is .9 that the error in the estimated average is not more than 1.645 standard error units one way or the other. This can be, and often is, expressed as a percentage of the average, for the iron-free data

$$\sigma_{\bar{x}} = \frac{21.2}{\sqrt{5}} = 9.49 \text{ mils}$$

$$\text{and } 1.645 \sigma_{\bar{x}} = 15.6 \text{ mils}$$

which is 44.6 percent of the normal expectancy of 35 mils penetration per year. Final results might be published in a manner similar to Table V.

A conclusion can be supported now which can be expressed substantially as follows:

"It can definitely be said that the presence of a small amount of iron is effective in reducing the rate of corrosion of this material in sea water. Quantitatively, iron free material may be expected to corrode at the rate of about 35 mils per year which can be reduced to around 7 mils per year by the addition of some .60 percent Fe.

"The probability is .90 that neither figure is in error by more than 45 to 50 percent. The true ratio has a .90 probability of being somewhere between 2 and 8.\*\* It is definitely established also that material containing iron will exhibit much more uniformity in corrosion rate from part to part than material that is essentially iron-free."

This may not be too encouraging but it really is a lot of information squeezed out of only five pieces of data. It, at least, gives us a better picture than might have been had otherwise.

### Sample Size

If one wishes to determine the number of observations to make in order to have a predetermined degree of precision in the final result, he has merely to assign a chosen allowable error to the above formula and solve for  $n$ . Thus: "How many tests of the iron containing material should be run in order to have about 90 percent assurance that the average corrosion rate determined will be within plus or minus 10 percent of its true value?"

$$1.645 \sigma_{\bar{x}} = 1.645 \frac{\sigma'}{\sqrt{n}} = .10 \bar{x}'$$

$$\sqrt{n} = \frac{(1.645)(4.02)}{.7}$$

$$n = 90$$

Note from the above that one may increase precision by reducing sigma or by increasing the number of readings. Reducing the scatter is much more effective but it also is apt to be the more expensive. Which to do in a given situation, depends upon economics entirely.

### Summary

To summarize, a simple method of estimating from a relatively few data what might have been obtained as an average value had there been a very large number of data is offered. At the same time a tool by

TABLE V  
Suggested Manner of Presentation of Final Results

Iron Content	Expected Corrosion Rate mils/Yr.	No. of Test	Standard Deviation	Possible Error*
.12 percent . . . . .	35	5	21.2	44.6%
.59 percent . . . . .	7	4	4.02	47.2%

\* The probability is .90 that the average corrosion rate is not in error by more than  $\pm$  the percent shown.

\*\* Hold the paper horizontally at eye level and squint down through the points with one eye.

\*\* This was established using a test beyond the scope of this paper. The true ratio has a .90 probability of being  $5 \pm 3.2$ .

which to judge the accuracy of the estimate just made has been provided. This was done at a probability level of .90 (9 times out of 10). Any other probability level can be used by changing the constant 1.645 to another, appropriate to the chosen level.\* Lastly shown was the means of deciding how many times the experiment must be repeated to achieve a given level of precision.

Check statistically the data being used. Do not accept it blindly without first examining it as to the probable limits of its accuracy. Often times a statis-

\* Some people prefer to use two standard units to yield a probability level of the order of .95.

tical examination will bring forth relationships that could not be seen otherwise.

For those who may wish to pursue the subject further two very good texts are recommended:

"Treatment of Experimental Data," by Worthing & Geffner (Wiley & Sons) is a general treatise on the mathematical handling of data and has an excellent section on statistical analysis.

The second is quite new and is a complete text on statistical methods. It is called

"Quality Control and Industrial Statistics." The author is A. J. Duncan and it is published by Richard E. Irwin, Inc., Chicago.



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TEXAS

# Topic of the Month

## Flotation Painting Gas Holders At 69,000 Square Feet an Hour

By L. B. DONOVAN\*

NINE YEARS ago consolidated Edison Company of New York, Inc. began experimenting with a new method of painting the large submersible surfaces of its many water-sealed gas holders. These water-sealed holders, familiar objects on the skyline of every sizeable community, operate much like the old-fashioned collapsible drinking cup. As gas is pumped in or out of a holder, its various sections or lifts, are alternately submerged in water and exposed to the atmosphere. Consequently, they are particularly susceptible to corrosive influences. Consolidated Edison sought a painting method which would be more corrosion-resistant than conventional methods.

What Consolidated Edison calls the "flotation" method was the result. The company's painting engineers sought and successfully developed a protective film of drying paint which could be floated on the sealing water and which would adhere to a descending lift surface as it passed through its submerging cycle. As a lift descends through the film of paint and into the water, positive hydraulic pressure forces the paint into the lift surface and distributes it uniformly. As the lift rises, surplus paint flows off, to float again on the water seal where it can be pumped off for re-use.

Before trying the new method on the vast expanse of a gas holder, a preliminary test was made by lowering a 40-foot length of 2-inch pipe in a water-sealed holder tank through a dam made by a bottomless five-gallon paint can which held three gallons of floating paint. The results encouraged further experimentation. Successively, the complications of initial gravity, viscosity, stratification, emulsification and the like were encountered and solved.

### Method Offered Royalty Free

After the ways and means of the flotation method were worked out and proved by the actual painting of gas holders, patents were applied for. They were granted in 1948 and 1949. U. S. Patent No. 2451158 covers the method and U. S. Patent No. 2462368 covers apparatus. Consolidated Edison, however, is not keeping its process to itself and is willing to grant, with certain stipulations, a royalty free license to any utility company. Many other companies have expressed deep interest. One, the Philadelphia Gas Works Company, has already put flotation to a full size test by painting one of its gas holders in this manner. The Public Service Electric & Gas Co., New Jersey, flotation painted a 2,000,000 cu. ft. and a 3,000,000 cu. ft. holders in August 1952.

So far, Consolidated Edison has used the flotation method to paint 31 gas

holders with a total lift area of more than 2,700,000 square feet.

The standard procedure begins after any necessary hand-scraping and spot priming, a costly operation which Consolidated Edison believes can be eliminated entirely by a proper finish painting interval.

Consolidated Edison's rig (Figure 1), which rolls to the job-site, includes a 1500-gallon tank truck filled with paint at the supplier's plant—thus eliminating packaging—and an army-surplus trailer carrying two screw-type electrically-driven pumps. In addition, there is a portable 2-inch hose ring line which can be assembled by means of fast couplings and without handtools in three hours—beside other auxiliary equipment.

### Ring Line Distributes Paint

The ring line, which has ten outlets in its circumference for the gas holder of average size, is placed around the tank walk, which skirts the water seal, and is connected through the trailer pump to the tank truck.

The lift to be painted is inflated with gas so it rises into the air and the sheets are permitted to dry.

Paint is then pumped to the water seal through the outlets (Figure 2). A stopwatch calibrated to pump performance is used to insure that a predetermined amount of paint is delivered to the various sectors of the ring line. This distribution is checked with a gage designed for the purpose, which consists of a float which will sink in paint but float on water. Any deficiency in paint volume is then supplied through the ring-line outlets. Gas is then pumped from the holder by the permanent station equipment. As the lift descends, the paint crew does a patrol job to detect thin spots in the floating paint. If, because of wind conditions or faulty loading readings more paint is required, the appropriate ring-line valves are opened to supply it.

As soon as the lift has reached the limit of its descent, the gas flow is reversed, causing the lift to rise. As it does, the surplus paint flows off onto the surface of the water seal. By reversing the trailer pump connections, this surplus paint is removed from the water seal back through the ring-line to the truck. Water picked up in this operation is either removed by opening a drain valve in the truck or the combined paint and water is pumped back to the holder for the next lift operation where the separation takes place naturally.

### Area Painted Decreases Second Day

Working a normal schedule for this type of paint job, a six-man crew will paint three lifts, about 66,635 square feet, the first day and two lifts, 45,067 square feet, the second day.

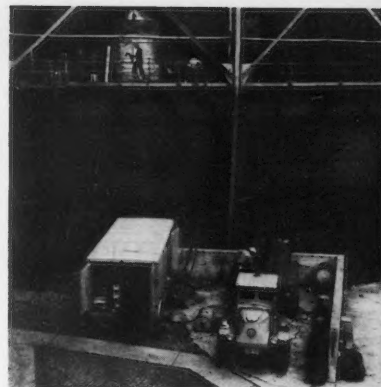


Figure 1—Consolidated Edison's flotation paint rig. The 1500-gallon tank truck at right picks up paint at supplier, eliminating packaging. Paint is sent by pumps in trailer at left, through riser to water seal.



Figure 2—Paint being loaded on water seal. Foreman with stopwatch, calibrated to pump performance, sees that predetermined gallonage is poured.

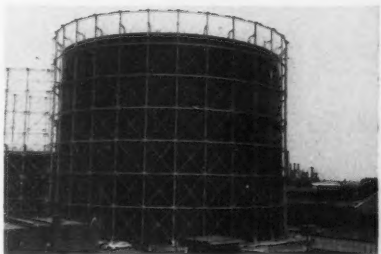


Figure 3—Flotation method painted this 15,000,000 cubic foot gas holder, one of the world's largest at the rate of 69,000 square feet an hour.

Cost of material when flotation is used is higher than in conventional painting. This is because more paint is used and the price per gallon is higher because of continued research, development and experimentation. Even so, the whole job cost of Consolidated Edison's first flotation jobs was only 90 percent of the cost of conventional job by brush or spray, while the five-year cost, based on per-

(Continued on Page 2)

\* Consolidated Edison Company of New York, Inc.

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## Flotation Painting—

(Continued From Page 1)



Figure 4—Advantages of flotation method are shown here after a few years' exposure. Upper section was painted by conventional brush method and the bottom section by flotation, using the same paint.

formance experience, is only 36 percent of any other known method.

Consolidated Edison's biggest flotation job was the painting of a 15,000,000 cubic foot holder (Figure 3) at its Astoria gas manufacturing plant, believed to be one of the largest water-seal holders in the world. Because of its great diameter (296 feet) every foot of vertical travel represented hundreds of square feet of surface. At a rising rate of 15 inches a minute, this amounted to more than 69,000 square feet an hour. At this rate, the walls of the average 12 by 18 foot room would be painted in less than 24 seconds.

Special formulations, pigmented with aluminum for gravity reasons, were used in early Consolidated Edison flotation jobs. While these produced excellent films from the durability standpoint, appearance was poor after a short operating period. This was due to a surface deposit of suspended yellow oxide picked up from the holder tank water. In terms of color contrast, the lift gave the appearance at a distance of complete paint failure.

### Paint Color Improves Appearance

Recent jobs have been done with a paint which approaches cordovan leather in color, uniformity of gloss, thickness and toughness. While this surface also picks up the yellow oxide, it is much less apparent because of the diminished color contrast.

The extreme durability (Figure 4) of the flotation-applied paint film on water-sealed holder lifts is attributed by Consolidated Edison painting engineers to the following factors:

1. Complete automatic impregnation of the old painted surface regardless of unequal local porosity conditions, i.e., absorption characteristics of the freshly spot-primed area and the adjacent relatively-spongy old paint.
2. Automatic, even distribution of the wet film after unequal surface absorption requirements have been fulfilled.
3. Uniform flow-off of surplus paint because of steady rate of operating movement.
4. Heavy wet film thickness, 4 to 6 mils, without runs or sags.





## Oil and Gas Line Central TP Committee Authorized

### Immediate and Energetic Development Of New Canadian Region Is Projected

#### Petition for Kansas City Section Is Received

Immediate and energetic development of the newly formed Canadian Region approved by the NACE board of directors at Chicago is expected under the leadership of G. I. Russell, Union Gas Company of Canada, Ltd., Chatham, Ontario, who has accepted the post of temporary chairman. Other temporary officers have been approached by Hugh P. Godard, of Aluminium Laboratories, Ltd., a director of the association, and their acceptances are expected soon.

This is the first major geographical change in the association's history, although there has been discussion from time to time concerning the advisability of authorizing organization of sections at points outside the geographical limits of the United States.

Mr. Godard proposed several activities for the interim group, principally steps to organize local sections at Toronto, Vancouver, Montreal, Calgary and Edmonton, where membership is sufficient to do so. It was further proposed that plans be made for a Canadian dinner meeting at the Chicago Conference in March when Canadian NACE members could discuss problems of the region.

Mr. Russell, petroleum engineer with Union Gas Company of Canada, Chatham, Ont., who has been spearheading the drive for new Canadian members and for recognition of the Canadian region, with the active cooperation of NACE members, has succeeded in bringing the number of Canadians who are members of NACE to 125. Of these 84 signed the petition to the association's board asking that a Canadian Region be recognized.

A nominating committee has been selected to propose a slate of candidates for regional officers to be voted on.

#### Kansas City Section

Opportunely, a petition has been forwarded from NACE members at Kansas City, asking that a section be recognized there. The section will be called upon almost at once to make a major contribution to the association because the 1954 Conference and Exhibition, the tenth national meeting of the association, is scheduled for Kansas City in 1954. This will be the twenty-eighth section organized by NACE.



#### NACE MEETINGS CALENDAR

##### 1953 Jan.

- 5—North Texas Section. Water and Sewage Problems of the City of Dallas by Henry J. Graeser, Dallas City Waterworks.
- 13—Cleveland Section. Joint meeting with Cleveland Electro-chemical Society. Recent Developments in Corrosion Laboratory Techniques.\*
- 13—Houston Section. Condenser Tube Alloys by A. W. Tracy.
- 20—Chicago Section. Stainless Steel Corrosion Failures by Barclay Morrison, Carpenter Steel Co.
- 27—Southwestern Ohio. Inco film "Corrosion in Action." Discussion by Roy O. McDuffie, University of Cincinnati.

##### Feb.

- 5—Pittsburgh Section. Corrosion in Heat Exchangers, by John J. B. Rutherford, Babcock & Wilcox Tube Co., Beaver Falls, Pa.
- 10—Houston Section. Stress Corrosion Cracking of Stainless Steels by S. E. Doughty, Carpenter Steel Co.
- 13—Philadelphia Section. Corrosion Inhibitors by Paul Cardwell, Dowell, Inc.
- 17—Chicago Section. Round Table Discussion on Protective Coatings.
- 17—Cleveland Section. Corrosion of Iron and Steel, by R. B. Hoxeng, United States Steel Company, Pittsburgh.

### Institute of Technology Professor Gets Award

J. Henry Rushton, professor chemical engineering and director of the department of chemical engineering at Illinois Institute of Technology, received the William H. Walker Award of the American Institute of Chemical Engineers at the society's Annual Awards Banquet in Cleveland, December 9. He was selected, "in recognition of his excellent publication record over the years in the fields of equipment design, mechanical mixing and engineering education."

The 12-issue subscription price of Corrosion to non-members of NACE is now \$9. The single copy price to non-members is \$1.

A central committee on oil and gas line corrosion problems similar to existing Technical Practices Committee 1 on Corrosion of Oil and Gas Well Equipment was authorized by the board of directors of the National Association of Corrosion Engineers at its December 6 meeting at Chicago. This action was taken in recognition of a resolution asking for the committee approved at the business meeting of South Central Region in New Orleans last October. The board also stipulated that in the future one of the delegate members of NACE on the Inter Society Corrosion Committee will be the chairman of the technical practices committee.

Preliminary arrangements were approved for the use of the auditorium at Kansas City for the exhibit to be held during the 1954 Conference there and it was decided the 1955 conference and exhibition would be held at New York City, during March at a place and on dates to be determined later.

Among the numerous other actions taken were:

The form of the certificates for sections was approved.

Formation of Canadian Region, and Atlanta and Jacksonville sections was approved.

The rate for 1954 subscriptions for the Corrosion Abstract Card Service was set at \$100.

A request from the North East Oklahoma Chapter of the American Society of Heating and Ventilating Engineers for a speaker on corrosion was turned over to N. E. Berry, NACE past president.

Philadelphia Section NACE will be asked to cooperate with the Instrument Society of America in presenting a program on corrosion during the First International Instrument Congress and Exposition to be held September 14-24.

Copies of the first specifications issued by the Steel Structures Painting Council will be sent to technical practices committee chairmen concerned with coatings.

### All Exhibit Space At Chicago Is Sold

The last of 107 booths in the original plan for the 1953 corrosion exhibit to be held during the March 16-20 Conference at Chicago was sold December 15. This is believed to be the earliest date an NACE exhibit has been sold out.

The 1954 Conference and Exhibition of the National Association of Corrosion Engineers will be held March 15-19 at Kansas City, Mo.



**METROPOLITAN NEW YORK SECTION** officials and the speaker at the meeting held in November. Left to right, front row, are: Kempton Roll, Lead Industries Association, section chairman; E. C. Reichard, Federated Metals Div., who introduced the speaker; and A. J. Liebman, Dravo Corp., who spoke on "Surface Preparation." Rear, left to right: W. R. Briggs, W. A. Briggs Bitumen Co., chairman of the Philadelphia Section; W. F. Fair, Jr., Koppers Co., nominee for NACE Director; H. W. Dieck, Long Island Lighting Co., secretary-treasurer of the North East Region; L. B. Donovan, Consolidated Edison Co. of New York, Inc., NACE Director representing the North East Region.

## Sudrabin Addresses N. Y. Section on December 3

L. P. Sudrabin, technical research director of the Electro Rust-Proofing Corp., Belleville, N. J., was the featured speaker at the December 3 meeting of the Metropolitan New York Section, held at Scharitz Restaurant, Manhattan. Mr. Sudrabin spoke on "Cathodic Protection—Its Place in the Scheme of Corrosion Control." An active period of discussion followed.

Newly elected officers of the Section will be installed by Chairman Kempton H. Roll, Lead Industries Association, at the January 21, meeting of the section. New officers will be: George Hull, Anglo American Varnish Co., chairman; Morton Berman, The Brooklyn Union Gas Co., vice-chairman; F. J. LeFebvre, Electro Rust-Proofing Corp., secretary-treasurer. Speaker for the January 21 Section meeting will be F. L. LaQue of International Nickel Co. who will analyze anomalies encountered in corrosion.

There were 130 members and guests at the December meeting, and according to a report by F. E. Kulman, the Christmas spirit of good will pervaded the dinner meeting. Through the courtesy of 20 manufacturers and suppliers, entertainment and gifts and door prizes were presented.

## Nichols Elected Head Of Chemical Engineers

William T. Nichols, director, general engineering department, Monsanto Chemical Co., St. Louis, Mo., has been elected president of the American Institute of Chemical Engineers for 1953. Also elected to other offices were Chalmer G. Kirkbride, vice-president; Stephen L. Tyler, executive secretary and C. R. DeLong, treasurer.

## Boston Section's First Anniversary Marked

Greater Boston Section celebrated its first anniversary with T. P. May, chairman of North East Region as guest Wednesday, December 10. The occasion was a social hour, dinner and evening meeting at Hotel Beaconsfield, Brookline, Mass.

The 58 members and guests, drawn from a membership trebled during the section's first year, were present to hear Dr. H. P. Meissner, professor of Chemical Engineering at Massachusetts Institute of Technology speak on "The Manufacture and Development of Titanium," and to participate in the question and answer period conducted by the speaker after his address.

Next meeting of the section will be February 4 when G. C. English, of Aluminum Company of America will speak on "Fundamentals of Corrosion."

## Shoan Talks Dec. 4 on Inhibitors in Coatings

Raymond A. Shoan, Dearborn Chemical Co., Chicago, spoke to Pittsburgh Section members at Mellon Institute, Pittsburgh, December 4. He gave a brief resume of the mechanism of inhibitors, and explained the use and importance of inhibitors in the non-drying coatings. His talk, "Inhibited Compounds and Their Importance in Corrosion Prevention," also covered inhibitors in paints, cooling water, brines, steam return lines, oil wells and in pickling and scale removing acid solutions.

## Early Christmas Fete Held at Philadelphia

Christmas was scheduled early for members of the Philadelphia Section. The section planned a dinner and Christmas party "with plenty of good cheer, door prizes and entertainment," according to George Decowsky, chairman of the fellowship committee. Members who could not attend the dinner and party were urged to attend the technical session and meeting and take part in the discussion.

Howard Bennett, section program committee chairman arranged for Walter A. Luce, Duriron Co., Dayton, Ohio, to speak on "Recent Trends in Stainless Steel and Other High Alloys." Dr. Luce in 1950-'52 wrote and edited "Materials of Construction Review" for the publication, "Industrial Engineering Chemistry."

On the agenda of the business meeting was the nomination and election of section officers for the coming year. Copies of the report of the nominating committee to be presented at the meeting were mailed to section members in advance.

The 1954 Conference and Exhibition of the National Association of Corrosion Engineers will be held March 15-19 at Kansas City, Mo.

## Vinyls and Polyvinyls Is Topic at Chicago

"Vinyl Resins and Rigid Polyvinyl Chloride," was the subject presented to members of the Chicago Section at the October 21 meeting held at the Chicago Engineers Club. H. M. Zimmerman of the B. F. Goodrich Company discussed the various forms of polyvinyl chloride from rigid rods and sheets which are welded together with a welding rod of polyvinyl chloride and a hot air gun (400-450° F.) to solutions of polyvinyl chloride in organic solvents for use as surface coatings. The physical properties and the chemical resistance of polyvinyl chlorides were also discussed. Seventy members and 15 guests attended the meeting.

## Use of Petroleum Rust Preventives Is Discussed by Vago

Southwestern Ohio Section of the NACE met October 28 under the guidance of Chairman Roy McDuffie. Members attending the first meeting of the section heard S. A. Vago give an interesting and well prepared talk on the use of petroleum rust preventives, according to Lewis M. Lederer, secretary. A discussion period followed Mr. Vago's talk. The meeting was concluded by a picturesque movie of development of the petroleum industry in Arabia. A total of 100 men attended.

## J. P. Oliver Is Speaker At St. Louis Meeting

J. P. Oliver of National Carbon Company addressed the December 8 meeting of St. Louis Section on "Recent Applications and Developments of Cathodic Protection" in which he covered pipelines, water tanks, brine wells, underground tanks and the food industry. Application to ships and docks was discussed also.

There were present 18 members and guests.

Vapor phase inhibitors, their present uses, potential uses and their properties in the packaging and chemical industries and in the military services were subjects of a panel discussion held at the November 10 meeting of the Greater St. Louis Section.

Warren Easley of Monsanto Chemical Co. acted as moderator and participated in the discussion. Edward S. French and Ben Levine of the Orchard Paper Co. were members of the panel.

Messrs. French and Levine told the section that one of the principal ways of combating corrosion was by the use of paper sacks, bags and wrapping paper which has been impregnated with the chemical.

## Wood Is Elected

Southwestern Ohio Section members have elected R. L. Wood to the office of treasurer. Other Section officers had already been elected, but in the regular election, the voting for the position of treasurer resulted in a tie, making a runoff election necessary.

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includes TIME TESTED METHODS of Application

For the past 20 years SOMASTIC PIPE COATING has been applied to pipe by standard practices which only now are being adopted generally by the pipe coating industry. Time has proved them most effective. These methods are—

- ★ *Thorough cleaning of metal by grit-blasting.*
- ★ *Pre-heating, followed by hot priming, assuring a firm, lasting bond of coating to steel.*
- ★ *Selection of materials and manufacture of coating to rigid specifications.*

In addition, SOMASTIC leads in this essential feature—

- ★ *Application of coating to primed pipe in a continuous process by special SOMASTIC equipment to form a dense, compact, uniform and seamless protective coating of great durability.*

The general swing to methods pioneered by SOMASTIC Pipe Coating is another acknowledgment of a fact first shown by the API-Bureau Of Standards Ten Year Pipe Coating Tests . . . and since proved at thousands of corrosive locations . . . for *permanence* coat with SOMASTIC.

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Unequaled for PERMANENT PROTECTION  
**SOMASTIC IS** The Best PIPE COATING

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# South East Region Sections Announced at Meeting

## Holsteyn Is Elected So. Central Director

Derk Holsteyn was elected Regional director for 1953 in the annual South Central Regional NACE election. Mr. Holsteyn received 490 votes. Harry Waldrip was elected Regional chairman with 449 votes; T. S. Moffatt, Jr. got 447 votes to win the vice chairmanship. Clifford L. Barr received 447 votes and will be secretary-treasurer. Elected assistant secretary-treasurer was John E. Loeffler with 447 votes. Voting was by mail and Mr. Moffatt, Buford P. Ledbetter and Fred C. Reeb counted the ballots.

## Chicago Hears Luce On Cast Iron Corrosion

Chicago Section members heard Walter Luce of the Duriron Company talk on "Corrosion Pertaining to Cast Iron and Alloys of Cast Iron," at the regular meeting held November 18, at the Chicago Engineers Club.

Mr. Luce discussed the various types of corrosion, the causes and some preventive measures which can be taken to decrease the rate of corrosion on castings.

No December meeting was scheduled and the next meeting was set for January 20, 1953.

## Harper Is Elected to Head Teche Section

Election of Teche Section officers to serve the remainder of 1952 and during 1953 has been announced. The emergency election was conducted at the November meeting of the section to fill vacancies in the organization.

George M. Harper, Union Oil Company of California was elected chairman. Mr. Harper lives in Abbeville, La. J. H. Waterfield, United Gas Corp., New Iberia, was elected secretary and treasurer. Gus Vogler, Brance-Krachy, Lafayette, La., was elected vice-chairman. Mr. Vogler will continue to handle programs for the section meetings.

A joint meeting with the Louisiana Engineers Society at Southwestern Louisiana Institute auditorium was scheduled for December with the International Nickel Co., Inc. film "Corrosion In Action" to be shown. Bob Bullock has been asked to introduce the film.

Mr. Vogler attended the Southeastern Regional NACE meeting in Atlanta, Ga. in October. He said it was the finest one-day program he had ever seen and that the hospitality was of the best.

## L. A. Hugo Is Named

L. A. Hugo, with Phillips Petroleum Co., Bartlesville, Okla., has been named general chairman of the 1953 South Central Region meeting to be held at Tulsa.

Approval of by-laws, formation of new Jacksonville, Florida Section, presentation of three technical talks and the showing of two films were highlights of the Fall meeting of the NACE Southeast Region.

On a motion by E. D. McCauley regional director, the by-laws were approved by a unanimous vote of the members. The by-laws which already had been reviewed by the NACE Central Office are now ready for printing.

Officers of the newly formed Atlanta Section were introduced. J. F. Johnston, A. T. & T. Company is the Atlanta Section chairman; Ray Trapp, Midway Engine and Equipment Co., is vice-chairman and Alex Erganian, Pipe Line Service Co., is secretary-treasurer. Tentative plans for an Atlanta Section luncheon meeting in January were announced.

## Jacksonville Section Formed

Regional vice-chairman Jack We announced the formation of the new Jacksonville Section. Chairman pro tem is Henry T. Rudolph of Atlanta Coatings Co., with H. E. Alexander, Dozier and Gay Paint Co., Jacksonville, Florida as vice-chairman. Mr. Rudolph stated that the Jacksonville Section would provide a forum for corrosion problems of the pulp and paper industry which has some 18 plants in the area. South boundary of the section was drawn across the bottom of Lake Okeechobee, but the north and west limits are as yet undetermined.

Speaker at the morning session of the Regional meeting was Dr. T. J. MacLand of A. T. & T. He discussed the problems of "Cathodic Protection of Long Lines Cables in the Southeast." In the afternoon, the film "Corrosion In Action" was shown. Dr. Ivy Park presented a paper detailing experience with the "Clean-up of New Production Pipe Lines."

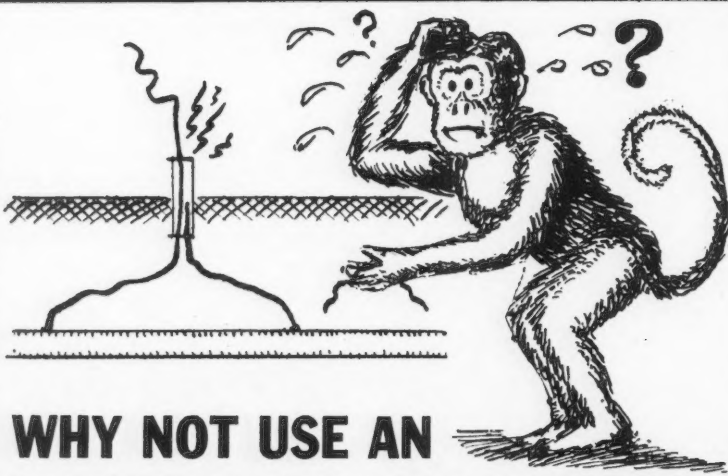
## Fertilizer Corrosion Discussed

Replacing Frank L. Whitney, Jr., Monsanto Chemical Co., Leroy Thompson of Southern National Gas Co., Birmingham, Ala., delivered a talk on "Corrosion Problems To Be Solved in the Manufacture of Fertilizer." Following Mr. Thompson's talk, a color film describing the "Phoscoating Process of Pickling Steel," was shown. The program concluded with an after dinner round table discussion on all three talks program speakers acting as a panel.

The nominating committee under chairman Pete Tait presented a slate of regional officers for 1953. Jack We Atlanta, Ga., Aluminum Company of America was nominated chairman; H. Van Nouhuys, Atlanta, Ga., Southeastern Pipe Line Co., vice-chairman and Dave Chadwick, Anniston, Ala., Monsanto Chemical Co., secretary-treasurer.

The NACE Committee on Education welcomes inquiries concerning the holding of cooperative short courses on corrosion. The association can frequently help with advice and otherwise educational institutions interested in holding such courses.

Many, but not all, back issues of Corrosion are available for sale.



**WHY NOT USE AN ELECTROLYSIS CHECK POINT?**

- ★ No broken wires
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# *Positive* CORROSION PROTECTION

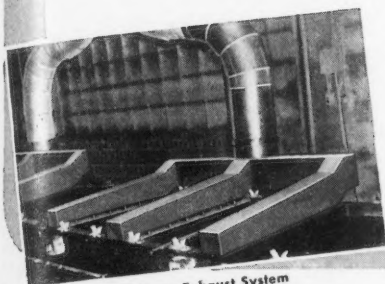
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Agilene designates the various specially selected grades of Polyethylene used in the various corrosion-resistant products and fabrications manufactured by the American Agile Corporation.

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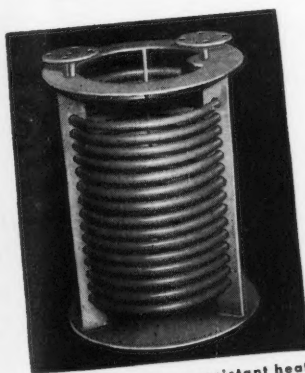
A new, specially developed, unplasticized Polyvinyl Chloride, resulting in an outstanding construction material for fabrication of equipment and apparatus in the chemical and allied industries.



Section of Acid Fume Exhaust System fabricated entirely from AGILENE.



Substructure of a Washing Machine for TV Picture tubes, containing Hydrofluoric Acid, fabricated throughout from AGILIDE.



Section of corrosion-resistant heat-exchanger system, using AGILIDE pipe and frame-work of fully welded construction.



AGILENE removable tank-liner, fitted into a plywood case.



Self-supporting 50-Gal. acid-mixture make-up tank, fabricated entirely from AGILIDE, including pipe fittings and flanges.

★ As pioneers and specialists in the field of thermoplastic fabrication and welding, we have the required knowledge and experience to design, fabricate, and assemble installations for various industrial purposes from these new construction materials offering outstanding resistance to corrosion.

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## Specifications for Pipe Coatings Discussed at Tulsa Section Meeting

"Specifications of Pipe Coating—Application and Inspection," by Gaines C. Laster, co-owner of the Tulsa Pipe Coating Co., was the topic of discussion at the Tulsa Section November meeting.

Although most of Mr. Laster's 24 years of experience has been in coating and wrapping pipe lines, his talk was of interest not only to those engaged in trunk pipe line corrosion work but also to those whose work is in solving plant piping corrosion problems.

Mr. Laster went to work for a pipe line contractor in 1928. In 1937 he became associated with Panhandle Eastern

Pipe Line Co. From 1938 through 1946 he was with the Barrett Co. as service engineer. He was supervisor in charge of the service department for the Barrett Company on both the "Big Inch" and "Little Inch" war emergency pipe lines. In 1946, Mr. Laster joined Ivan L. Brunkow to form the Tulsa Pipe Coating Company.

Manuscripts on subjects dealing with Corrosion from any source are considered for publication in CORROSION magazine. The association, in general, prefers not to publish material which has appeared in other readily available periodicals, or which consists solely of an advertising sales message. Copies of the NACE "Guide for the Preparation and Presentation of Papers" are available on request.

## North Texas Section Elects J. C. Spaulding

Election of section officers for the coming year highlighted the December 1 meeting of the North Texas Section at the Venus Restaurant in Dallas.

New officers, elected by mail ballot are: J. C. Spaulding, Jr., Sun Oil Co., chairman; Morris Bock, Sun Oil Co., vice-chairman; Maryann Duggan, Magnolia Petroleum Co., secretary-treasurer. The term of office started January 1 and new officers were to take over the first meeting of the new year, January 5.

At the December meeting, H. M. Cooley, assistant metallurgical engineer, Bethlehem Steel Co., Tulsa, Okla. spoke on the "Effects of Various Metallurgical Characteristics of Steel on Its Resistance to Corrosion." There were 25 Section members and 14 guests at the meeting.

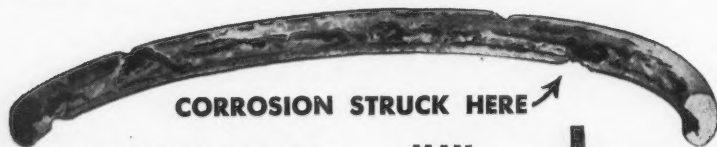
## PESCO Ring Joint GASKET

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PESCO has answered the demand for a stronger, safer ring gasket with the PESCO RING JOINT GASKET made of FIBERGLAS and special synthetic resins. They are built for rugged and rough handling in the field and no re-machining is required for re-use.



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This steel ring was removed from a gas well in northern Louisiana, and was replaced by PESCO Ring Joint Gasket.

MAY  
STRIKE  
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## PESCO RINGS

PESCO Rings are built to withstand compression pressures in excess of 60,000 psi and internal pressures in excess of 15,000 psi, with moisture absorption less than 1%. They are unaffected by liquid and gasses encountered in oil and gas systems. Shaped for quick, easy installation to API ring groove specifications.

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## Corpus Christi Changes Day of Meetings

Beginning with the January meeting, the Corpus Christi Section will meet on the fourth Tuesday of each month. Previous meetings were held the fourth Wednesday of each month. There was no meeting scheduled for December.

Section members attending the November meeting heard W. B. Moore of the Reynolds Metals Co. speak on "Development of Aluminum Sucker Rods for Oil Wells." Mr. Moore illustrated his talk with a sound color movie. Among the distinguished guests were M. A. O'Bannon and J. R. Akers, both of the Louisville office of the Reynolds Metals Co. and Bob Rowan of Rowan and Buchanan, Houston.

## Grizzard Is Western Region's New Chairman

Western Region's new officers for 1953 are as follows:

E. H. Grizzard, Signal Oil & Gas Co., Los Angeles, chairman; Austin S. Joy, Bechtel Corp., Somatic Division, Wilmington, Cal., vice-chairman; Robert H. Kerr, Southern California Gas Co., Los Angeles, secretary-treasurer.

## San Francisco Section

The San Francisco Bay Area Section met November 19, for dinner at Alouette Restaurant, San Francisco. Thirty-six members and guests attended. The International Nickel Co., Inc. color film "Corrosion in Action" was shown.

## Godard Accepts Post

H. P. Godard of Aluminum Laboratories Ltd., Kingston, Ontario has accepted the post of chairman of the 1954 Corrosion Principles Symposium, a part of the technical program for the NACE conference to be held at Kansas City that year. Dr. Godard will serve also as co-chairman for the corrosion principles symposium at the Chicago meeting in March.



## Stevens Seminar on Corrosion Features Lectures for Public

The public is invited to join regularly enrolled students in attending lectures by guest speakers and participating in discussions at the 1953 Stevens Institute of Technology "Corrosion Prevention Seminar." Members of the National Association of Corrosion Engineers will be charged a \$10 fee for the eleven lectures, each of which begins at 7:15 pm on Thursday nights. The seminar begins February 5 and ends May 21. NACE is cooperating in presentation of the seminar.

Non-members of NACE will be charged a \$15 fee, while non-members of NACE who apply for membership in NACE at time of registration will pay \$17.50, of which amount \$7.50 covers one year's dues.

Regularly enrolled students have five scheduled class sessions, in addition to the eleven lectures, at which they will report on special topics assigned to them, according to R. S. McCormick, Lecturer on Corrosion at Stevens Institute, who is in charge of arrangements. Non-students will be admitted to classes only with special permission.

Speakers for the 16 sessions will be: T. P. May, F. L. LaQue and E. Allen Tice, International Nickel Co., Inc.; C. L. Bulow, Bridgeport Brass Co.; L. P. Sudrablin, Electro Rust-Proofing Corp.; A. Black, Shell Development Co.; F. A. Lowenheim, Metal and Thermit Corp.; G. Oxley, Standard Oil Co. of New Jersey, and K. Tator, Coraopolis, Penna.

At the first meeting, students will see a corrosion movie produced by The International Nickel Co. At other sessions, the date, subject and the speaker will be: February 12, "Review of Corrosion Factors," T. P. May, International Nickel Co., Inc.; February 19, "Iron and Stainless Alloys," F. L. LaQue, International Nickel Co., Inc.; February 26, Class Meeting (no speaker, for students only); March 5, "Copper and Its Alloys," C. L. Bulow, Bridgeport Brass Co.; March 12, "Light Metal Alloys," H. W. Fritts, Aluminum Company of America; March 19, Class Meeting (no speaker); March 26, "Nickel and Its Alloys," E. A. Tice, International Nickel Co., Inc.; April 9, "Cathodic Protection," L. P. Sudrablin, Electro Rust-Proofing Corp.; April 16, class meeting (no speaker); April 23, "Inhibitors," A. Black, Shell Oil Company; April 30, "Metal Coatings," A. G. Gray, Steel Magazine; May 7, class meeting (no speaker); May 14, "Paints and Inorganic Coatings," G. Oxley, Standard Oil Development Co.; May 21, "Plastics and Rubber," K. Tator, Coraopolis, Pa.; and May 28, examination for students.

## Illinois Short Course Scheduled Oct. 12-16

A change has been made in the dates for holding the 1953 University of Illinois Short Course on Cathodic Protection. The new date has been set as October 12-16 inclusive. The course will be held at the University, Urbana, Ill.

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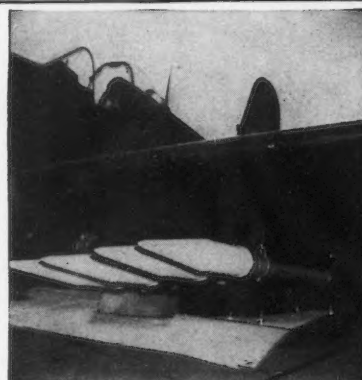
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### Technical Service Data Sheet

### Subject: IMPROVING PAINT ADHESION ON STEEL WITH GRANODINE®

#### INTRODUCTION

"Granodine" is a zinc phosphate coating chemical which improves paint adhesion on steel, iron and zinc surfaces. In the Granodizing process, a non-metallic crystalline coating is formed on the treated metal. This bond holds and protects the paint finish and thus preserves the metal underneath.



Official Dept. of Defense Photograph

An F4U Corsair with the Navy's new aircraft anti-tank rocket, the "RAM". A Grade I zinc phosphate finish (JAN-C-490) protects the entire external surface of this rocket and provides a durable bond for the specification paint finish.

#### "GRANODINE" MEETS SERVICE SPECIFICATIONS

JAN - C - 490, Grade I	CLEANING AND PREPARATION OF FERROUS METAL SURFACES FOR ORGANIC PROTECTIVE COATINGS
JAN - F - 495	FINISHES FOR EQUIPMENT HARDWARE
U.S.A. 57-0-2C Type II, Class C	FINISHES, PROTECTIVE, FOR IRON AND STEEL PARTS
U.S.A. 51-70-1, Finish 22.02, Class C	PAINTING AND FINISHING OF FIRE CONTROL INSTRUMENTS; GENERAL SPECIFICATION FOR
MIL - V - 3329	VEHICLES, COMBAT, SELF-PROPELLED AND TOWED; GENERAL REQUIREMENTS FOR

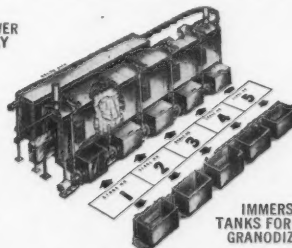
#### GRANODIZING DATA

Granodizing is an easily applied chemical process. Depending on the size, nature and volume of production, Granodizing can be carried out by spraying the parts in successive stages of a power washing machine, by dipping the work in the cleaning, rinsing and coating baths contained in tanks, or by brushing or flow coating the work with portable hand equipment. Typical process sequence and equipment requirements are shown below:

MULTI-STAGE POWER  
WASHER FOR SPRAY  
GRANODIZING

#### PROCESS SEQUENCE

1. Clean
2. Rinse
3. "Granodine"
4. Rinse
5. Final Rinse



IMMERSION  
TANKS FOR DIP  
GRANODIZING

NOTE: Equipment can be of mild steel throughout, except in the Granodizing stage, where nozzles, risers, and pump impeller should be of acid-resistant material.

#### MANY APPLICATIONS

Automobile bodies and sheet metal parts, refrigerators, washing machines, cabinets, etc.; projectiles, rockets, bombs, tanks, trucks, jeeps, containers for small arms, cartridge tanks, 5-gallon gasoline containers, vehicular sheet metal, steel drums and, in general, products constructed of cold-rolled steel in large and continuous production are typical of the many products whose paint finish is protected by "Granodine".



WRITE FOR FURTHER INFORMATION ON "GRANODINE" AND YOUR OWN METAL PROTECTION PROBLEMS.



## Six Nuclear Engineering Corrosion Sessions Added by U. of Cal.

Six conference sessions related to corrosion in nuclear engineering have been added to the program for the University of California, Berkeley, Corrosion Short Course, to be held February 2-6. The talks are presented in cooperation with the radiation laboratory of the university and will be held at 155 Dwinelle Hall.

Four speakers to present this part of the program have been named as follows:

C. R. Bredon of the Reactor Engineering Division, Argonne National Laboratories, who will speak on the corrosion of stainless steel.

J. E. Draley, corrosion researcher with the Metallurgy Division of Argonne Laboratories, who will discuss corrosion of aluminum.

Leo F. Epstein, of the General Electric Power Laboratory at Schenectady,

whose subject will be corrosion by liquid metals.

Earl T. Hayes, Chief of the Physical Metallurgy Branch for Region II, Bureau of Mines, will speak also.

The schedule of these sessions is:

### Wednesday—February 4

Radiotracer Techniques in Corrosion Detection, 7:30 to 9:30 pm.

### Thursday—February 5

Corrosion by Water and High Temperature and Pressures.

Problems. Corrosion of zirconium, 1:30 to 3 pm.

Corrosion of stainless steel, 3:10 to 3:50 pm.

Corrosion of aluminum, 4 to 5 pm.

### Friday—February 6

#### Special Topics

Corrosion by Liquid Metals, 2:40 to 3:50 pm.

Radiation damage to materials of construction, 4 to 5 pm.

The University Extension Department of Conferences and Special Activities has registered persons from throughout the nation already. Inquiries should be addressed to that office. NACE is cooperating with the university in presenting the course.

The schedule for the course was announced as follows by the university:

### Monday—February 2

Registration—8:30 to 9 am.

Fundamentals—W. F. Seyer, Department of Engineering, University of California, Los Angeles, chairman.

Welcome—9 to 9:15 a.m. Baldwin M. Woods, vice-president, University Extension and Professor of Mechanical Engineering, University of California, Berkeley.

Introduction to Study of Corrosion. Definitions, Magnitude, Types, Sources of Information. 9:15 to 10:15 am. I. Cornet, Division of Mechanical Engineering, University of California, Berkeley.

Fundamentals of Corrosion—Physicochemical factors. 10:25 to 12 noon. Norman Hackerman, Department of Chemistry, University of Texas, Austin.

Fundamentals of Corrosion. Metallurgical and Mechanical Factors. 1:30 to 3:20 pm. M. G. Fontana, Department of Metallurgy, Ohio State University, Columbus.

Stress Corrosion. 3:30 to 5 pm. J. J. Harwood, Metallurgy Branch, Department of the Navy, Office of Naval Research, Washington, D. C.

### Tuesday—February 3

Materials of Construction. Norman Hackerman, chairman.

Ferrous Metals. 9 to 10:50 am. V. V. Kendall, National Tube Division, United States Steel Company, Pittsburgh.

Non-Ferrous Metals. 11 am to 12 noon. 1:30 pm to 2:50 pm. W. Z. Friend, Corrosion Engineering Section, The International Nickel Co., Inc., New York.

Special Metals and Alloys. 3 to 5 pm. M. G. Fontana.

### Wednesday—February 4

Coatings. A. Wachter, Shell Development Co., Emeryville, Cal., chairman. Chemical Conversion Coatings. 9 to 10:50 am. G. W. Seagren, Stoner-Mudge, Inc. Fellowship in Protective Coatings, Mellon Institute of Industrial Research, Pittsburgh.

Metal Coatings. 2:40 to 5 p.m. A. Mendizza, Bell Telephone Laboratories, Murray Hill, N. J.

### Thursday—February 5

The Environment and Its Treatment. Mark F. Adams, Division of Industrial Research, Washington State Institute of Technology, The State College of Washington, Pullman, chairman.

Process Industry. 9 to 11 am. F. L. Whitney, General Engineering Dept., Monsanto Chemical Co., St. Louis. Public Water Supplies. 11:10 to 12 noon. F. L. Whitney.

### Cathodic Protection

Cathodic Protection Principles. 1:30 to 3 pm. Harold A. Robinson, Metallurgical Laboratories, Dow Chemical Company, Midland, Mich.

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in  
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Chemical conversion films, formed by metal-finishing chromates, provide good paint adherence and corrosion protection on zinc, cadmium, aluminum, magnesium, iron and steel. These finishes are non-electrolytic, and should not be confused with those resulting from anodizing. The metal to be treated is simply immersed in the chromate-containing solution for a short period during which, according to accepted theories, the chromium combines with the basis metal to form a thin, complex oxide film. This film differs from chromate primers in that it becomes an integral part of the metal surface.

These chemical processes which employ sodium chromate, sodium bichromate and chromic acid are invaluable in extending the use of scarce metals in both military and civilian production. When compared to anodizing they have the advantage of being cheaper and quicker.

For further information, write to Mutual's Research and Development Department.

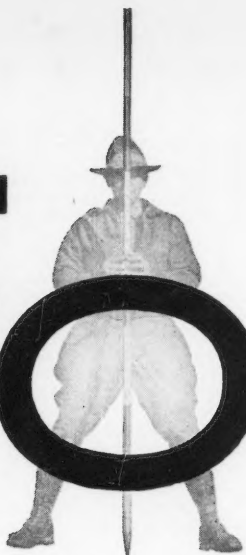
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(Continued on Page 12)

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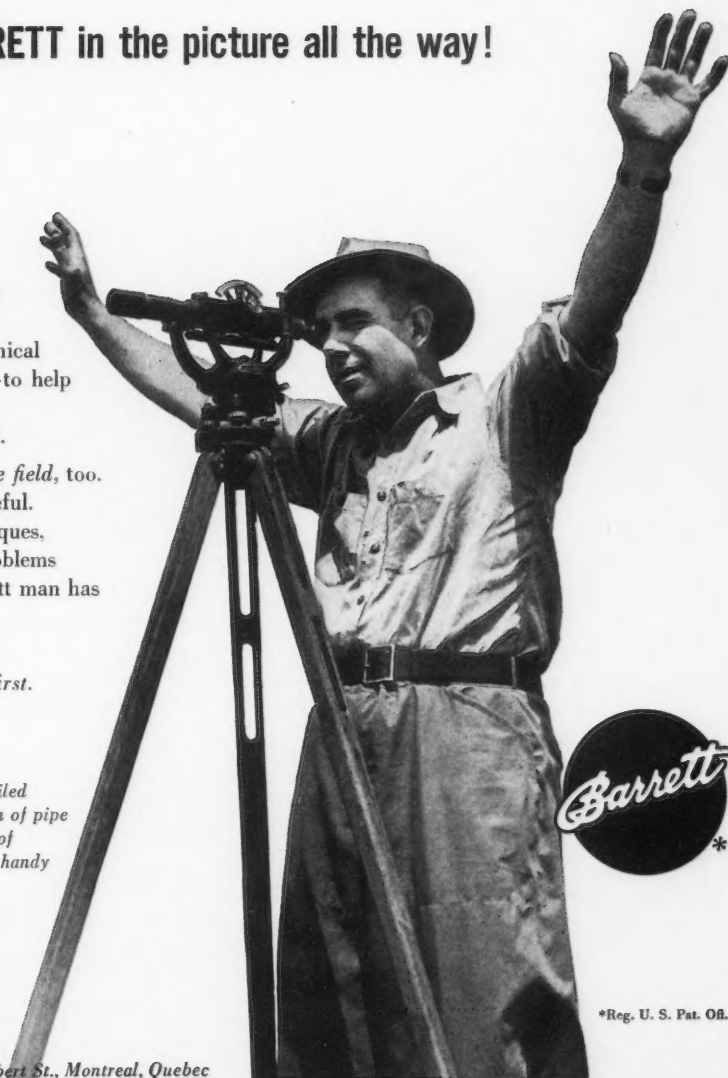
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## Aims of Technical Practices Committee 5 Reoriented on an Industry Scheme

### TP-6G Report Being Studied for Printing

Three years of work by members of Technical Practices Committee 6G, Surface Preparation for Organic Coatings, has culminated in a committee report which members have approved for submission to NACE as a tentative report for the next year.

A. J. Liebman, chairman of the committee has suggested that a future possible objective of the committee would be investigating problems of coatings for non-ferrous materials, mainly concentrating on coatings for aluminum.

Mr. Liebman explained that the American Welding Society has fairly well completed compilation of the surface preparation standards for metallizing and that the American Society for Testing Materials is presently in the process of setting up pictorial standards for classifying ferrous surfaces for painting.

Members have been asked to give their opinions on whether it is advisable for the committee to take up investigation of coatings for non-ferrous metals as its next field of investigation.

### Abstracts of Japanese Technical Material To Be Used by NACE

A new source for corrosion abstracts to be published in CORROSION, official publication of NACE which will be available also to subscribers to the NACE Corrosion Abstract Punch Card Service has been announced by the NACE Abstract Committee.

The abstracts, written in English, will summarize Japanese technical papers and will give the results of work on corrosion problems by Japanese scientists. The abstracts will be supplied by Hayata Shigeno, secretary of the Committee for Preventing Corrosion of the Japanese Society for the Promotion of Science.

Besides being secretary of the Corrosion Committee, Mr. Shigeno is a research worker at the Tokyo Industrial Testing Laboratory. He has been working on cathode corrosion problems since the end of the war, and has been investigating the use of aluminum-zinc anode systems.

The Japanese Society for Promotion of Science is a nation-wide body, originally organized in 1923 for the purpose of advancing armament science. The Corrosion Committee known as the 97th Sub-Committee, is one of the special committees functioning under the Society. This Committee has taken up problems of corrosion in equipment of the chemical industry. Since 1950 the committee has considered corrosion problems in all branches of basic and applied science. The thirty present members of the committee include college professors, members of research institutions and practicing engineers of leading industrial organizations.

The aims of NACE Technical Practices Committee 5 on Corrosion Problems Involved in Processing and Handling Chemicals have been reoriented to an industry scheme. H. W. Schmidt, chairman of the committee, in making the announcement of changes in designation of sub-committees said difficulties experienced by the original five sub-committees in gaining definitive information caused members to reexamine the committee's organization. It is believed that by narrowing the scope of the several subcommittees to cover the problems incident to corrosion by specific causatives, and, therefore the industries associated with the causatives, that definite progress can be made in the reduced areas by concentrating the attack.

Two of the subcommittees, TP-5B and 5E have been discontinued and the title of one changed and two new subgroups added.

Changes in the schedule of subcommittees, with chairman are:

The title of TP-5D is now "Corrosion by Acetic Acid." H. O. Teeple, corrosion Engineering Section, The International Nickel Co., Inc., New York, is chairman.

Committees added are:

TP-5F—Corrosion by Chlorine. R. I. Zimmerman, Westvaco Chemical Div., Food Machinery and Chemical Corp., S. Charleston, W. Va. is chairman.

TP-5G—Corrosion by Nitric Acid. J. L. English, Oak Ridge National Laboratory, P. O. Box P, Oak Ridge, Tenn. is chairman.

Mr. Schmidt reiterated the standing invitation to anyone interested in the topics concerning these committees to communicate with the responsible chairman. It is not necessary for a person to be a member of NACE to participate in the work of the technical committees, although it is more convenient to be.

### Six Nuclear Engineering—

(Continued From Page 10)

Catholic Protection Practices. 3:10 to 5 pm. A. W. Peabody, Ebasco Services, Inc., New York. Dinner, auditorium International House, 6 p.m.

#### Friday—February 6

Special Topics in Corrosion. I. Cornet, chairman. Corrosion Testing and Evaluation. 9 to 10:30 am. R. S. Treseder, Shell Development Co., Emeryville.

Design of Equipment from the Corrosion Standpoint. 10:40 to 12 noon. 1:30 to 2:30 p.m. A. Wachter.

Metals at High Temperature. Oxidation and Structural Stability. James G. Kerr, C. F. Braun and Co., Alhambra, Cal.

The Role of the Corrosion Engineer in Industry. 4 to 5 pm. Vance N. Jenkins, Research Div., Union Oil Co., Los Angeles, Cal.

Abstracts published in the Corrosion Abstract Section of Corrosion are indexed according to the system compiled for use with the association's Corrosion Abstract Punch cards.

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## Nine Steel Painting Surface Preparation Specifications Issued

The first nine specifications of a proposed series on steel painting practice have been issued by the Steel Structures Painting Council. The council is an organization composed of nineteen trade and engineering organizations interested in painting methods, including the National Association of Corrosion Engineers.

The Steel Structures Painting Council was organized in the spring of 1950 and work was started February 1, 1951 at Mellon Institute, under Dr. Joseph Bigos, who is director of research and secretary of the council. The first nine specifications, all dealing with surface preparation, have been prepared in loose leaf format. The council is preparing a Steel Structures Painting Manual for issue sometime this year consisting of two parts: Part I, chapters by various authors discussing present good practice in painting steel structures and Part II suggesting specifications for paints and painting, including outstanding paint systems. The council further contemplates cooperation in large scale paint tests by other organizations and also making tests of its own.

### Surface Preparation

The nine surface preparation specifications are: Solvent Cleaning, Hand Cleaning, Power Tool Cleaning, Flame Cleaning of New Steel, Blast Cleaning to "White" Metal, Commercial Blast Cleaning, Brush-Off Blast Cleaning, Pickling and Weathering and Cleaning. The whole series of nine specifications can be obtained for \$1 from the Secretary, Steel Structures Painting Council, 4400 Fifth Ave., Pittsburgh 13, Pa. Single Specifications may be obtained for 25 cents each.

The specifications approach the problem of surface preparation realistically, establishing practical standards of cleanliness where possible. The method of doing the work has been left open when possible and in some cases it was found possible to obtain the desired end result by specifying the operations involved only. Significant also is their toleration of residues in amounts not considered detrimental, rather than including such requirements as "All rust shall be removed by wirebrushing." The specification were sent for criticism to over 100 specialists before publication.

### More to Be Issued

Four subcommittees have been established in the council's research committee to keep the specifications up to date and provision has been made to issue additional specifications in each of the series when advisable. Criticism of specifications is welcomed by the research committee.

## Technical Data Digest

The publication "Technical Data Digest" a periodical containing abstracts of material compiled by the Armed Services Technical Information Agency has been suspended. For the past several months contents have been restricted, but previously material from it has appeared in Corrosion Abstracts.

## Fourth Annual Tulsa Short Course Set

The Fourth Annual Tulsa Short Course for Pipeliners with the theme "Practical Control of Pipe Line Corrosion" is scheduled to be held March 4-6 inclusive. W. A. Hutchison, Sinclair Pipe Line Company, general chairman of the course, said the program will be similar to that of previous years with discussion sessions at the Mayo Hotel and field demonstrations near Tulsa.

Further information will be available soon from Hugh A. Brady, Pipe Line Anode Corp., Box 996, Tulsa.

## BOOK REVIEWS

**Fatigue and Fracture of Metals, a Symposium.** Edited by William M. Murray, Massachusetts Institute of Technology. 313 pages. Published by John Wiley & Sons and, The Technology Press, Massachusetts Institute of Technology. \$6.00.

The book presents the views of 18 specialists at a special conference on the fatigue and fracture of metals held in June 1950 at the Massachusetts Institute of Technology.

The volume includes the following discussions: General Survey of the Problems of Fatigue and Fracture, The Fatigue Problem in Airplane Structures, Brittle Fracture and Fatigue in Ships, Brittle Fracture and Fatigue in Machinery, Internal Stresses and Fatigue, Designing for Fatigue, and Fundamentals of Brittle Behavior in Metals.

Further contributions include: Experimental Study on Temper Brittleness of Slightly Alloyed Carbon Steel, The Statistical Aspect of Fatigue Failures and Its Consequences, A Review of Cumulative Damage in Fatigue, Significance of Transition Temperature in Fatigue, The Influence of Metallographic Structure on Fatigue, Fatigue at Elevated Temperatures and The Techniques of Physical Metallurgy for Studying Fatigue Damage.

**The Fight Against Rust.** By Corrosion Committee of the British Iron & Steel Research Association, 11 Park Lane, London W 1. 25 pages, 9 3/4 x 6 1/2 inches, illustrated. Per copy 2 s. 6 p. (approximately \$0.30).

The booklet presents a general explanation of the rusting process, plus an estimate of the cost of corrosion to the British nation at 200,000,000 pounds sterling. Illustrated case histories are given, examples being selected from various corrosive environments, such as air, fresh and salt water and soil.

The booklet shows by various pictorial graphs and proportional drawings, the rate of corrosion of various steels in different environments. Pictures of test installations and exposure testing sites are given. In a summary and practical conclusions it is stated that prevention of corrosion is possible by one or more of four methods: a) deliberate alterations in the corrosive medium. b) modification in the design of plant or apparatus exposed to corrosion. c) changes in the composition of the steel. d) efficient protective measures.

(Continued on Page 16)



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Swimming pool diving tower at Shamrock Hotel, Houston, Texas, being metallized with pure aluminum by the F. W. Gartner Co., in early 1949. In perfect condition June 1952.

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Lincoln Pk. 25 (Detroit), Mich. <b>DIX ENGINEERING CO., INC.</b> 1417 Dix Road Tel. Dunkirk 1-8822	Philadelphia 29, Pa. <b>METALWELD, INC.</b> Fox & Hunting Park Ave. Tel. Radcliff 5-3471	St. Louis 10, Missouri <b>ST. LOUIS METALLIZING COMPANY</b> 625 South Sarah Street Tel. Newstead 5253	Brooklyn, N. Y. <b>ARTHUR TICKLE ENGINEERING WORKS, INC.</b> 21 Delevan Street Tel. Main 5-4200	Houston, Texas <b>F. W. GARTNER CO.</b> 3805 Lamar Avenue Tel. Atwood 5338

## BOOK REVIEWS

(Continued from Page 14)

**Marine Fouling and Its Prevention.** By The United States Naval Institute, Annapolis, Maryland. 400 pages 10½ x 8, illustrated. Per Copy, \$10.

Cost of barnacles and other fouling organisms costs the U. S. Shipping Industry alone more than \$100,000,000 yearly. The book details research done by the Bureau of Ships, Navy Department and Woods Hole Oceanographic Institution. The book is recommended to commercial shipowners and operators, to ship yards, managers of docks and piers to yacht owners, and to manufacturers of marine construction materials and paints and to any shore industries utilizing sea water for industrial purposes.

In one New England power station utilizing sea water, 266 tons of marine shells have been removed from the salt water tunnel within a single year.

The book relates the early attempts at developing an anti-fouling protection for ship bottoms. In 1625, Britain issued patents for an antifouling ship-bottom paint, but it was not until over 200 years later that the first fairly successful preparation was formulated—copper sulfate in yellow soap. Cost of docking, scraping and bottom-painting the superliner United States is estimated at \$75,000. More than a decade ago, cost of docking, scraping and painting the bottom of an 18,000 ton ship was \$4400. The price is higher now.

The book is written in three parts. Part I: "Problems of Fouling," takes up the Effects of Fouling and Ship Resistance. Part II is titled: "Biology of

Fouling." Part III: "Prevention of Fouling" takes up the prevention of fouling with toxics, the physical chemistry of compounds of copper and mercury and their interaction with sea water, mechanisms of release of toxics from paints, characteristics of anti-fouling coatings, the design of anti-fouling paint, the testing of anti-fouling paints, the fouling of metallic surfaces, interaction of anti-fouling paints and steel and other like topics.

**Fifty-Year Index to ASTM Technical Papers and Reports, 1898-1950.** 6 x 9 inches, cloth, 207 pages. American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. Per Copy, \$6.00. (ASTM members \$4.75)

This book consists of an author index, subject index, list of special technical publication series, list of compilation of standards and list of symposiums and topical discussions. Author index includes titles and reference, while topical index refers to author and reference only.

**Brief Subject and Author Index of Papers in the Proceedings, 1937-1951.** The Institution of Mechanical Engineers, Storey's Gate, St. James Park, S. W. 1., London. 5½ x 8½, 108 pages, paper.

Papers are indexed under topics in the first part and the author list is keyed to the subject list. Availability is not indicated.

Inquiries concerning advertising in Corrosion should be addressed to Central Office NACE, 1061 M & M Building, Houston 2, Texas.

## Company Affiliations Sought for Directory

In order to make the 1953 NACE membership directory more useful to all members, each active or junior member's company affiliation is included after his name in the directory listings when the information is available. This year, a business reply card on which the member may write his business affiliation is being included in the envelope containing the invoice for 1953 NACE membership dues.

Each member who has changed company affiliations or whose company affiliation does not appear on the invoice, can fill in the prepaid business reply card and drop it in the mail. The Central Office must have the cards by January 12 in order to be included in the 1953 Directory. The membership directory is compiled from the member's mailing address.

When the member has requested his correspondence be sent to his residence, his company affiliation is not shown. Therefore, members whose company affiliation is not shown on their invoice must fill in and mail the business reply card if their business connection is to be shown in the 1953 NACE membership directory.

Paid circulation of Corrosion has increased every year since the magazine was founded.

The 1954 Conference and Exhibition of the National Association of Corrosion Engineers will be held March 15-19 at Kansas City, Co.

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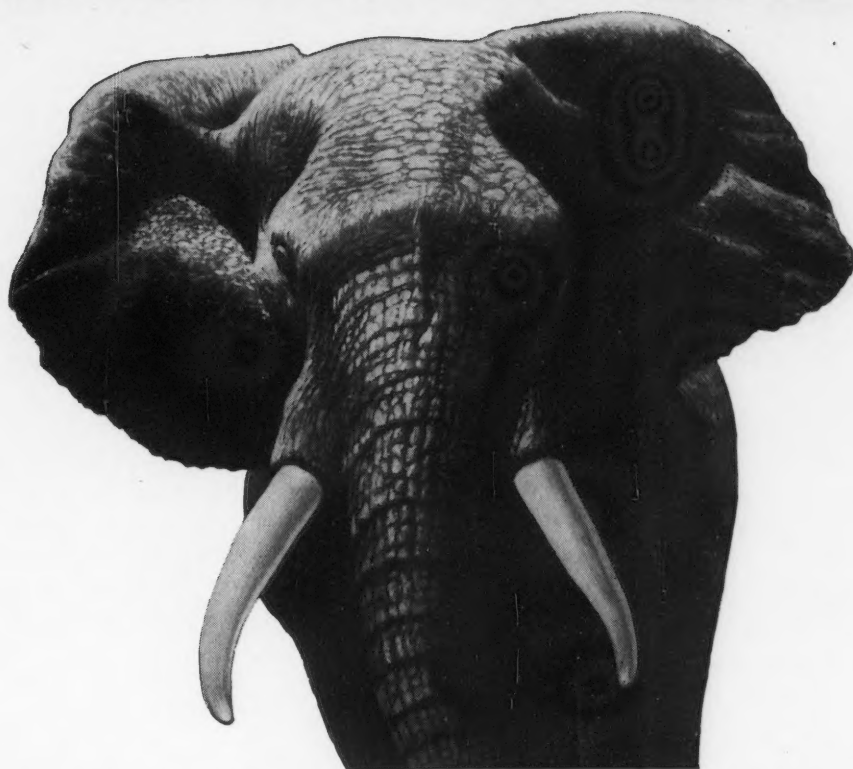
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## Inter Society Committee CORROSION MEETINGS CALENDAR

- Jan. 12-16**—Society of Automotive Engineers. Annual meeting, Detroit, Mich. Hotel Sheraton-Cadillac. (Symposium on Surface Treatments to Prevent Wear—January 13.)
- Mar. 3-5**—SAE National Passenger Car, Body and Materials Meetings, Detroit, Mich. Hotel Sheraton-Cadillac. (Some papers on automobile corrosion.)
- Mar. 16-20**—Annual Conference and Exhibition, National Association of Corrosion Engineers, Chicago. Sherman Hotel.
- Apr. 12-16**—The Electro-chemical Society, Spring Meeting, New York City. Statler Hotel.
- Apr. 13-16**—American Gas Association—Distribution, Motor Vehicles and Corrosion Conference, Chicago. Sherman Hotel.
- May 10-15**—American Water Works Association—General Convention, Grand Rapids, Mich. (Two papers on corrosion control.)
- May 11-14**—Midyear Meeting of American Petroleum Institute, Session on Corrosion of Refinery Equipment, New York, N. Y. Commodore Hotel.
- June 4-6**—Protective Coatings Division Meeting, Annual Chemical Institute of Canada Conference, Windsor, Ont.
- June 15-18**—American Electroplaters Society, Annual Meeting, Philadelphia. Benjamin Franklin Hotel. (Some papers on corrosion.)

**July 20-25**—AAAS Gordon Research Conference on Corrosion, New London, N. H.

**August**—Symposium on Corrosion, Association Committee on Corrosion Research and Prevention of National Research Council of Canada.

**Sept. 13-17**—The Electro-chemical Society, Fall Meeting, Wrightsville Beach, N. C., Ocean Terrace Hotel.

## Steel Founders' Society Given ATAE Award

Steel Founders' Society of America, was the winner of the 1952 Award of Merit conferred by the American Trade Association Executives, international society for professional trade association executives.

Presentation of the award for distinguished service by a national association was based on the judgment of a five-man jury of awards of which Charles Sawyer, Secretary of Commerce, was the chairman. Other members included William J. Grede, president, National Association of Manufacturers; Dechard A. Hulcy, president, Chamber of Commerce of the U. S.; Edward H. Stromberg, director, publicity and publications, Northwestern University; and Dr. Ray B. Westerfield, professor of economics, Hall of Graduate Students, Yale University.

The award was made at the annual meeting of A. T. A. E. in Toronto, Canada. Among other things, the Society was praised for "technical research in raw materials, products and uses, current statistics, market surveys to widen the use of steel castings, advertising, public relations, unfair trade practices, and liaison with engineering colleges."

## Instrument Society Meeting

The Instrument Society of America will hold its sixth annual regional meeting February 18, 1953, at the Penn top suite of the Hotel Statler, New York, N. Y. The New York Section of the Society is in charge of the program. The technical program consists of technical sessions covering process instrumentation, power plant instrumentation, and biological instrumentation. Principal speaker at the banquet will be H. S. Bean, Chief, Capacity, Density and Fluid Meters Section, Mechanics Division, National Bureau of Standards. He will speak on "Future Research and Development in Fluidmetering." Several papers will be delivered.

## ASM Foundation for Education Established

A \$650,000 foundation for education and research in engineering has been established by the American Society for Metals. Dr. Harold K. Work, director of the Research Division, New York University College of Engineering was named a trustee of the fund. Dr. Work is a past president of the Society.

The foundation is said to be the largest ever established by a technical society and was set up because of the grave shortage of engineering students and the importance of metals research to national security. Other trustees for the foundation are: Dr. Arthur E. Focke, Indianapolis, Ind.; Walter E. Jominy, Detroit, Mich.; Dr. John Chipman, Winchester, Mass.; and Ralph L. Wilson, Canton, Ohio.

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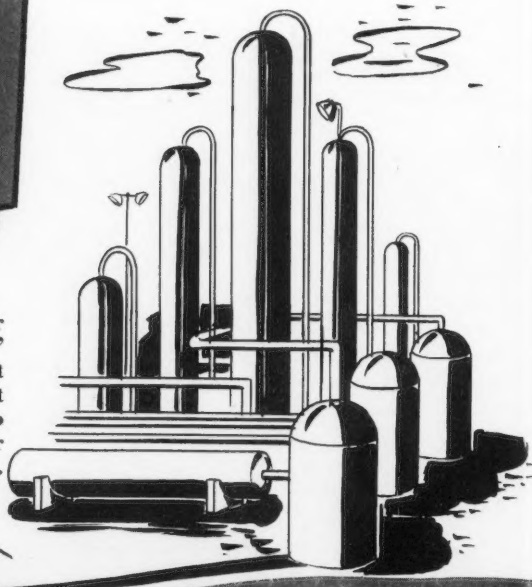
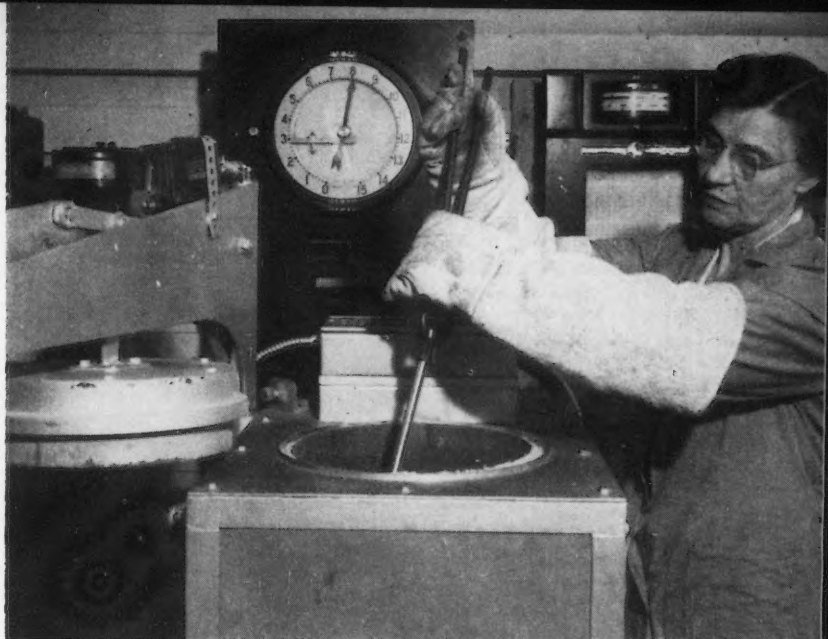


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Figure 1—National Bureau of Standards metallurgist placing specimen rod in electric furnace during NBS investigation of the solubility of carbon in austenitic stainless steel. High-purity iron-nickel-chromium alloys with various additions of carbon were specially prepared at the Bureau. Specimen rods of these alloys were held in the furnace at 800 degrees F for six weeks to precipitate carbon in excess of solubility at that temperature. Finally, samples of each rod were held at various higher temperatures to redissolve the precipitated carbides up to the limit of solid solubility. Values of solubility obtained at NBS were appreciably lower than those previously reported.



## Solubility of Carbon in Stainless Steel\*

AUSTENITIC stainless steels, which are characterized by a distinctive crystal structure, are widely used because they combine superior resistance to corrosion with ease of working. Properties and applications of these steels are considerably affected by the amount and form of carbon they contain. Many experimental studies have been made of various properties of these steels; but surprisingly little attention appears to have been given to the determination of the limit of solubility of carbon in one of the most widely used forms of stainless steel, chromium-nickel austenite.

Because of the importance of such knowledge, the National Bureau of Standards recently made a study of the solubility of carbon in austenitic stainless steel containing 18 percent of chromium and 10 percent of nickel. These levels of chromium and nickel were chosen as representative of the widely used AISI Types 302 and 304 stainless steels, frequently termed "18-8" steels. Sponsored by the Navy Bureau of Aeronautics, the investigation was conducted by Samuel J. Rosenberg and Carolyn R. Irish of the NBS metallurgy laboratories.

The bureau investigators found that with a carbon content of 0.007 percent, the lowest content studied, solution was substantially complete between 1300 degrees and 1400 degrees F. Solubility appeared to increase approximately linearly from about 1400 degrees to 1975 degrees F, the maximum temperature studied, where carbon solubility was approximately 0.08 percent. These values of solubility are appreciably lower than those previously reported. The solubility

curve developed at NBS indicates that Type 304 ELC (extra low carbon) stainless steel can be effectively annealed at 1700 degrees F, but that ordinary Type 304 stainless should be annealed at temperatures in excess of 1900 degrees F if the carbon is to be fully dissolved. The NBS study also points up limitations on the effectiveness of attempts to eliminate intergranular embrittlement of austenitic 18 percent Cr-10 percent Ni steel by reducing carbon content.

The annealing of austenitic stainless steels is often governed by the desire to obtain a completely austenitic structure—that is, a structure in which all carbon is in solution in gamma iron. To attain this end, annealing temperatures used in commercial practice are quite high, usually about 1950 degrees to 2000 degrees F. From another standpoint, however, such high annealing temperatures are undesirable; annealing at lower temperatures results in smaller grain size, which is thought to reduce susceptibility to intergranular embrittlement. Since the temperature at which all carbon is in solution increases with carbon content, it seems to follow that low-carbon steels may be annealed at lower temperatures than the higher-carbon varieties. In the absence of definite knowledge of the carbon solubility, however, it has been necessary to keep annealing temperatures quite high in order to assure an austenitic structure. For these reasons the results of the NBS study have considerable practical as well as theoretical interest.

The specimens investigated at NBS were high-purity iron-nickel-chromium alloys containing various additions of carbon ranging from 0.007 to 0.30 percent. All alloys were melted and solidified in vacuum. Ingots thus formed (weighing about two pounds each) were hot-forged to about 0.6-inch diameter,

annealed at 1975 degrees F, and cleaned by grinding to about 0.5-inch diameter. Half of each rod was then cold drawn. All of the resulting specimens, both as annealed and as cold drawn, were next

(Continued on Page 21)

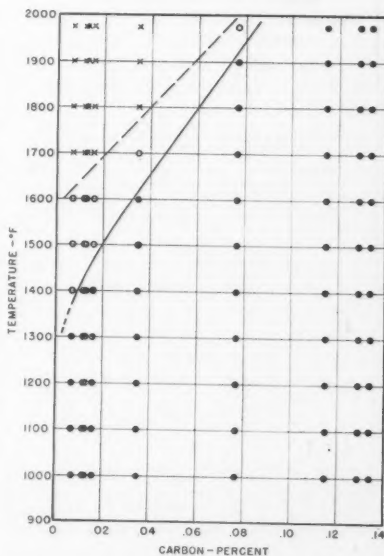


Figure 2—Results of the National Bureau of Standards study of solubility of carbon in high-purity austenitic alloys containing 18 percent of chromium, 10 percent of nickel, and balance iron. The solid line indicates the limit of substantial solubility; the dashed line indicates temperatures at which even the most minute traces of carbides are dissolved. (Solid circles, carbides; open circles, slight traces of carbides; crosses, no carbides.)

\*For further technical details, see "Solubility of Carbon in 18-Percent-Chromium-10-Percent-Nickel Austenite" by Samuel J. Rosenberg and Carolyn R. Irish, *J. Research NBS*, 48, 40 (1952) Jan. RP. 2281.

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# NACE

## New Members and Changes of Address

- This list is published principally for use by NACE Regional and Sectional officers in keeping their mailing lists up to date.

### NEW MEMBERS

(Additions through November 27, 1952)

#### CALIFORNIA

DODDS, DALE I., 1830 So. Eighth St., Alhambra, Cal.  
KALETSCH, K. G., Inertol Co., Inc., 27 South Park, San Francisco, Cal.  
MOLLER, GEORGE E., Union Oil Co. of California, Oleum Refinery, Rodeo, Cal.  
PUGH, LAWRENCE R., Beckman Instruments, Inc., 820 Mission St., South Pasadena, Cal.  
STARK, RICHARD I., Coast Counties Gas & Elec. Co., P. O. Box 4, Concord, Cal.  
**DISTRICT OF COLUMBIA**  
MARQUIS, SAMUEL A., Glass Fibers, Inc., 1010 Vermont Ave., N. W., Washington 5, D. C.

#### ILLINOIS

KNICKERBOCKER, ROBERT E., The Texas Co., R. R. No. 2, Salem, Ill.  
SHERWOOD, B. C., Commonwealth Edison Co., 72 West Adams St., Chicago 90, Ill.

#### INDIANA

GRUCA, E. P., Res. & Dev. Dept. Pullman-Standard Car Mfg. Co., 1414 Field St., Hammond, Indiana.

#### KANSAS

PHIPPS, HARRY K., Socony-Vacuum Oil Co., Inc., Central Pipe Lines Div., 917 1st Natl. Bank Bldg., Wichita 2, Kansas.

#### MARYLAND

YOUNG, LUTHER O., The Davison Chemical Corp., Curtis Bay, Baltimore 26, Md.

#### MASSACHUSETTS

CLOUGH, PHILIP J., National Research Corp., 70 Memorial Drive, Cambridge 42, Mass.  
PRUNARET, HENRI H. N., Hartwell & Son, Inc., 31 State James Ave., Boston 16, Mass.

#### MICHIGAN

BOSTWICK, JAMES M., Stel Sales Corp., 5151 Wesson, Detroit 10, Mich.

#### MISSISSIPPI

DRAKE, JULIAN D., Mississippi Chemical Corp., Yazoo City, Miss.

#### NEW YORK

LEINS, ERNEST K., Solvay Process Div. of Allied Chemical & Dye Corp. Tech. Serv., P. O. Drawer 271, Syracuse, N. Y.

#### TEXAS

LEE, JAMES F., Beaumont Iron Works, Beaumont, Texas.

RIDDICK, McDONALD L., Magnolia Petroleum Co., Box 3311, Beaumont, Texas.

MILLER, JACK D., United Centrifugal Pumps, a Div. of United Iron Works, 523 West Bldg., Houston, Texas.

#### FOREIGN

GREY, JOHN R., B. C. Electric Co., 129 Keefer St., Vancouver, B. C. Canada.

HETHERINGTON, JOHN A., Petroleum Development Qatar, P.C.L., Qatar, Via Bahrain, Persian Gulf.

LIBBY, HUGH T., British Columbia Elec. Co., Ltd., 425 Carrall, Vancouver 4, B. C., Canada.

LOGIE, JOHN S., Burrard Dry Dock Co., East Esplanade North Vancouver, B. C. Canada.

LUCAS, J. W., Testing Laboratories, Dept. of Public Works, Ottawa, Ontario, Canada.  
McHARDY, GEORGE, Catholic Corrosion Control, Ltd., 73 South Audley St., London W. 1, England.  
NAGHSHINEH, CYRUS, c/o National Iranian Oil Co., Ahwas, Iran.  
REES, WALTER N., Catholic Protection Co., Ltd., 2901 Douglas St., Victoria, B. C., Canada.

### CHANGES OF ADDRESS

(Old Address Follows New in Parenthesis)

FLYNN, HUGH F., Macco Corporation, 14409 Paramount Blvd., Paramount, Cal. (Mugh.)  
GOEN, PAUL S., Dekoron Tubing, 1341 So. Hope, Los Angeles 15, Cal. (Delete Zin-clate.)  
GREEN, E. F., Axelson Mfg. Co., Div. of Pressed Steel Car Co., Inc., Box 15335 Vernon Station, Los Angeles 58, Cal. (Div. of Pressed Steel Car Co., Inc.)  
NOSS, OSCAR F., JR., 2512 Knoxville Ave., Long Beach, Cal. (1222 East 1st St.)  
RADCLIFF, THOMAS D., 1550 Del Mar Ave., San Marino, Cal. (Standard Oil Co. of Cal., Ridgeview Hotel, Evanston, Ill.)  
SCHIFF, MELVIN J., Electro Rust-Proofing Corp., 1713 So. California Ave., Monrovia, Cal. (Box 178, Newark, N. J.)  
STOKES, WILLIAM S., Pipeline Coating & Engineering Co., 3850 East Florence Ave., Huntington Park, Cal. (National Pipe Coatings, Inc., 2800 E. Randolph St.)

(Continued on Page 22)

### Solubility of Carbon—

(Continued From Page 19)

held at 800 degrees F for six weeks to precipitate carbon in excess of the solubility at that temperature. Finally, samples were held at various higher temperatures to effect re-solution of the precipitated carbides up to the limit of solid solubility. (The excess carbon not in solid solution was present as chromium carbide ( $Cr_{23}C_6$ )).

Several methods for determining the limit of carbon solubility were tried, but only metallographic examination proved feasible. This was complicated, however, by the presence of ferrite and sigma in many of the samples. It was noted that sigma was a stable phase in the lower-carbon alloys, particularly in the temperature range of about 1000 degrees to 1300 degrees F.

The use of Type 304 ELC steels in industry is based on the premise that the low carbon content (0.03 percent maximum) will give some protection against intergranular embrittlement. Such embrittlement results when austenitic stainless steels are subjected to temperatures in the range of about 800 degrees to 1400 degrees F and are either simultaneously or subsequently exposed to the action of certain corrosives. Intergranular embrittlement has been ascribed to the precipitation of chromium

## POSITIONS WANTED and AVAILABLE

- Active and Junior NACE members may run without charge two consecutive advertisements annually under this heading, not over 35 words set in 8 point text type.
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**Chemical Engineer**—Familiar with materials of construction and corrosion problems to be technical staff man to evaluate and recommend, also develop methods for mfg. chemical-proof equipment. Advise experience and salary desired. Heil Process Equipment Corp., 12901 Elmwood Ave., Cleveland 11, Ohio.

**Corrosion Engineers.** Positions available for graduate electrical engineers or equal. Previous field and design experience in corrosion mitigation systems required. Extensive travel involved. Salary open. The Hinchman Corp., Engineers, Francis Palms Bldg., Detroit 1, Mich.

carbide at the grain boundaries of the austenite and it has been proposed that the phenomenon might be completely inhibited by reducing the carbon content to less than the limit of solubility at temperatures to which the steel will be subjected. Although these extra-low-carbon steels have been shown to be less susceptible to intergranular embrittlement than the higher carbon varieties, the NBS study indicates that it is impracticable, if not impossible, to produce steels with carbon contents sufficiently low to insure freedom from carbide precipitation under all conditions of service.

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## Changes of Address—

(Continued From Page 21)

**TOTAH, NADIM P.**, P. O. Box 301, China Lake, Cal. (Dorm. B-12, Room 3, U. S. N. O. T. S., Inyokern.)

**WATTS, ADMIRAL A.**, Research Dept., C. F. Brown & Co., Alhambra, Cal. (728 Alton Ave., Columbus 3, Ohio.)

### COLORADO

**BROCK, CHELSEY L. JR.**, 933 Uvalde, Denver 8, Colorado. (7930 E. 16th Ave.)

**SCHMUCK, HOWARD K. JR.**, 1595 King St., Denver, Colorado. (P. O. Box 201, Granby, Colorado.)

### GEORGIA

**PECK, E. J. JR.**, Amercoat Corp., 620 Coventry Rd., Decatur, Georgia. (333 Candler Bldg., Atlanta, Georgia.)

### ILLINOIS

**JOHNSON, THOMAS E.**, 1432 West Empire St., Freeport, Ill. (Illium Corp., Foot of Exchange, Freeport, Ill.)

### KANSAS

**SCHOFER, NATHAN**, 328 N. Quentin, Wichita, Kansas. (Hydrocarbon Research, Inc., 115 Broadway, New York 6, N. Y.)

### LOUISIANA

**FRIZELL, GLENN H.**, 271 E. McCormick, Shreveport, La. (103 E. Slattery.)

**KUHLMANN, FRANK H.**, Dearborn Chemical Co., 2723 Fairfield Ave., Shreveport, La., 1218 Olive St., St. Louis, Mo.)

### MICHIGAN

**COATES, PROCTOR G.**, Michigan Bell Telephone Co., 312 Potawatomi Blvd., Royal Oak, Michigan. (618 Boulevard Bldg., 7310 Woodward St., Detroit 2.)

**PINNER, W. L.**, Houdaille-Hershey Corp., 9120 Roselawn Ave., Detroit 4, Michigan. (403 Midland Ave., Highland Park 3, Mich.)

### MISSISSIPPI

**LOVELL, ODUS W. JR.**, United Gas Pipe Line Co., P. O. Box 8337, Station D, Jackson, Miss. (240 Bon Air.)

### MISSOURI

**KENYON, C. PATRICK**, Research Lab., Sheffield Steel Corp., Sheffield Station, Kansas City 3, Mo. (Research Lab., omitted.)

**WOODWARD, HENRY F. JR.**, Spencer Chemical Co., 610 Dwight Bldg., Kansas City 6, Mo. (P. O. Box 604 Pittsburg, Kansas.)

### NEBRASKA

**HAAS, W. B.**, Supt. of Pipelines RC, Northern Natural Gas Co., 310 Aquila Court Bldg., Omaha 1, Neb. (Asst.)

### NEW JERSEY

**KUBICKY, EDWARD W.**, Devoe & Reynolds, Rutherford & Delancy, Newark, N. J. (Reynolds.)

**TALBOT, DANIEL W.**, 252 Munsee Way, Westfield, N. J. (Vice Pres., Cooper Alloy Foundry Co., Ramsay & Bloy St., Hillside, N. J.)

### NEW YORK

**ANSON, E. H.**, Gibbs & Hill, Inc., 491 Pennsylvania Station, New York 1, New York. (E. K. Anson.)

**BISHOP, ROBERT W.**, 185 Price St., Lockport, New York. (Harrison Radiator Div. G. M. C., Washburn.)

**PIRSH, EDWARD A.**, Babcock and Wilcox Co., 161 East 42nd St., New York 17, N. Y. (85 Liberty St.)

**SICKMAN, EDISON C.**, The Atlas Mineral Products Co., 475 Fifth Ave., New York, N. Y. (2404 Highland St., Allentown, Pa.)

**STOBAUGH, ROBERT B. JR.**, California Texas Oil Co., Ltd., Eng. Dept., Second Floor, 546 Fifth Ave., New York 17, N. Y. (c/o Creole Petroleum Corp., Las Piedras, Edo. Falcon, Venezuela, S. A.)

**WINCHESTER, CHARLES L.**, 27 Monroe Place, Brooklyn 2, N. Y. (130 Eighth Avenue, Apt. 7E.)

### OHIO

**MULHERAN, BERNARD C.**, 30311 West Lake Rd., Bay Village, Ohio. (3252 W. 100th St., Cleveland, Ohio.)

### OKLAHOMA

**HAHN, A. H.**, Crane Co., P. O. Box 2649, Tulsa 1, Oklahoma. (2548)

**JOHNSTON, JOHN E.**, Oklahoma Natural Gas Co., P. O. Box 871, Tulsa, Oklahoma. (1620, Oklahoma City.)

**POLSTON, J. R.**, Vice Pres., Service Pipe Line Co., P. O. Box 1979, Tulsa, Oklahoma. (General Mgr.)

### PENNSYLVANIA

**BANKS, JOHN B.**, Glass Fibers, Inc., 132 E. Second St., Media, Pennsylvania. (1810 Madison Ave., Toledo 6, Ohio.)

**BIGGS, JOSEPH**, Steel Structures Painting Council, Mellon Institute—1400 Fifth Ave., Pittsburgh 13, Pa. (Mellon.)

**DAVIS, L. W.**, 1830 W. 11 St., Erie, Pa. (Aluminum Co. of America, 2210 Harvard Ave., Cleveland, Ohio.)

**GAMBOW, LEWIS J.**, Pioneer Alloy Products Wks. of National Lead Co., Millview & Early Sts., Ellwood City, Pa. (16601 Euclid Ave., Cleveland, Ohio.)

## NEW PRODUCTS—Materials — Service — Literature

"Manual of Metal Preparation Chemicals Used Prior to Application of Protective and Decorative Coatings," by A. J. Hereford, general manager, metal processing division, Tesco Chemicals, Inc. Atlanta, Ga. is a 28-page bulletin. Chapter headings, indicative of subject matter contained are: Metal Preparation for Paint and Other Protective Coatings, Including Phosphate Processing, Cleaning, Paint Stripping and Pickling, Selecting a Phosphate Process or Conditioner, List of Phosphoric Processes for Corrosion Proofing and Paint Bonding Metal, including use, equipment, auxiliary operations and chemicals and operational instructions; Preparing Large Units for Protective and Decorative Coatings Fabricated Out of Steel, Aluminum and Zinc; General Information and Instructions for Phosphate Processing; List of Phosphoric Compounds for

Cleaning and Conditioning Metal Use; Equipment; Tests and Controls; Cleaning; Alkali Cleaning Compounds for Metal; and Preparing Aluminum for Painting.

**The Earl Paint Corp.**, 240 Genesee St., Utica 2, N. Y., are publishers of a 24-page catalog listing coatings for industrial maintenance, including corrosion-resisting, insulating, waterproofing and restoration materials. The catalog lists the composition, qualities, uses, tests technical data and tables showing the chemical, corrosion and fire resistance, as well as insulation qualities of various Erkote Mastics.

**American Wheelabrator & Equipment Corp.**, Mishawaka, Ind. has moved its New York City district office to 53 Newark Street Bldg., Hoboken, N. J.

## PERSONALS

**Donald H. Bond**, chairman of NACE Technical Practices Committee 3, "Anodes for Use with Impressed Currents," is ill in the Houston Veteran's Administration Hospital. Although Mr. Bond's condition is said to be satisfactory, it is believed he will be in the hospital for some time. The hospital is located at Alameda Road and Holcombe Blvd. Visiting hours are from seven to nine p.m. daily, and three-thirty to four-thirty, Saturday, Sunday and Wednesday.

**R. F. Ledford** has been appointed director of sales and research, Industrial Filter & Pump Mfg. Co., 5900 Ogden Ave., Chicago 50, Ill. Mr. Ledford was formerly superintendent of finish, Sunbeam Corp. He is a member of the Electrochemical Society and American Society for Testing Materials.

**Ernest H. Wyche**, member of NACE Technical Practices Subcommittee 5C, Subsurface Corrosion by Alkaline Solutions, has recently joined the firm of Kenneth Tator Associates, Corapolis, Pa. Mr. Wyche has held positions with the Colgate-Palmolive-Peet Co., Materials Engineering Division; the Lukens Steel Co. and the United States Steel Corp. He has received national recognition for his work in the precipitation hardening of stainless steels. In his work with Kenneth Tator Associates, Mr. Wyche will concentrate on corrosion preventive methods in research, in operations and technical sales. He is a graduate in chemistry of the University of North Carolina, a registered professional metallurgical engineer, a member of several technical societies and is the author of numerous technical publications and of several patents.

**Richard Schermer** has been named manager of pump sales for the Duriron Co., Inc., Dayton, Ohio. Mr. Schermer joined Duriron in January, 1952 as building equipment sales manager. In other appointments, **R. A. Prosser** was made manager of building equipment sales, and **Wendell A. Watkins** was promoted to Chicago District Manager from Buffalo. He was succeeded by **D. E. Christie** who was made manager of the Buffalo Sales Territory.

### TEXAS

**ADAMS, ROBERT H.**, Box 514E, Rt. 16, Houston, Texas. (Catholic Protection Service, 4601 Stanford.)

**ARMSTRONG, BOB J.**, 421 Hulsache, Lake Jackson, Texas. (415 West Main St., Houston 6.)

**BASKETT, FOREST**, Rheem Manuf. Co., 1025 Lockwood Drive, Houston, Texas. (P. O. Box 2102.)

**BROWN, GEORGE F.**, Standard Brass & Manuf. Co., Box 1469, Port Arthur, Texas. (K. C. S. & 4th St.)

**CARMICHAEL, CHARLES J. JR.**, 5810 Hilary St., Houston, Texas. (441 North Union, Opelousas, La.)

**PERKINS, GEORGE M.**, 1233 Williston St., Tampa, Texas. (Creole Petroleum Corp., Apartado 889, Caracas, Venezuela, S. A.)

**PYOTT, WILLIAM T.**, 4028 Law St., Houston, Texas. (Mannix Ltd. Calgary, Alberta, Canada.)

**RODGERS, JAMES W.**, Dowell, Inc., General Delivery, Devine, Texas. (Box 830, Lafayette, La.)

**SHAY, NEIL E.**, The American Brass Co., 1521 Fidelity, Union Life Bldg., Dallas 1, Texas. (1205 Irwin-Kessler Bldg.)

**SMITH, O. R.**, Smith Contracting Corp., Rt. 6, Box 211, Fort Worth, Texas. (1206 Continental Life Bldg.)

**SNEDAKER, DELBERT G.**, 6022 Bellfort Ave., Houston 21, Texas. (1905 Colquitt, Apt. 3.)

**VANCE, THOMAS L.**, South Chester Tube Co., 1605 Oil & Gas Bldg., Ft. Worth 2, Texas. (307 Life of America Building.)

**WATSON, WILLIAM ELMER**, 2903 Fernwood, Dallas 16, Texas. (2442 Stovall Dr.)

**WIMER, CHARLTON J.**, 1407 S. Akard, Dallas 1, Texas. (527 2nd Unit Santa Fe Bldg.)

### VIRGINIA

**GAMMACHE, ROBERT L.**, 1246 Oakwood St., Bedford, Virginia. (514½ Mansion Rd., Elmhurst, Wilmington, Delaware.)

### WISCONSIN

**KOPPL, FREDERICK**, 749 North 31 St., Milwaukee 8, Wisconsin. (James G. Biddle Co., 20 W. Jackson Blvd., Rm. 602, Chicago 4, Ill.)

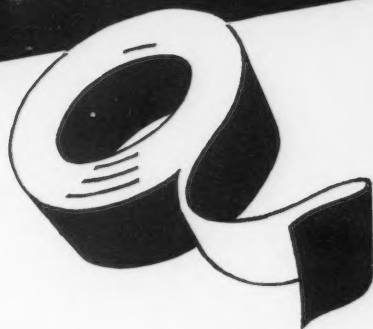
**PLEODERL, FRANCIS J.**, Wisconsin Protective Coating Co., Box 358, Green Bay, Wisconsin. (426 Elizabeth St.)

### FOREIGN

**HURLEY, E. T.**, Canadian National Railways, 1801 Leber St., Montreal, Quebec, Canada. (360 Sebastopol.)

**GERRARD, JOHN S.**, 10, 9th Street North, Ahmadi, Kuwait, Persian Gulf. (c/o 41 Merton Road, Prestwich, Nr. Manchester, Lancs., England.)

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## Four Pipe Line Sessions Are Scheduled at Chicago

Full recognition will be given to the important place held by the pipe line industry in the nation's transportation scheme during the NACE Ninth Annual Conference and Exhibition. Four sessions have been scheduled for pipe liners during the March 16-20 Conference at the Sherman Hotel, Chicago. They are a round table discussion of General Pipe Line Problems, of which M. C. Callahan of Gulf Refining Company's Tulsa Pipe Line Division will be chairman; Pipe Line Coatings, with E. R. Lopez of The Barrett Division, Allied Chemical & Dye Corp., New York, as chairman; Cathodic Protection Symposium, with E. P. Doremus, of Cathodic Protection Service, Houston, as chairman and Pipe Line Group Discussions, to be moderated by A. L. Stegner, Tennessee Gas Transmission Co., Houston.

The session under the leadership of Mr. Callahan will be held from 2 to 4:15 p.m. Thursday, March 19 and will consist of an open discussion of pipe line problems. Similar sessions have been the highlights of past conferences.

Mr. Lopez has selected ten persons acquainted with various aspects of the pipe line coating industry to participate in the discussion.

The Group Discussions Symposium under the direction of Mr. Stegner is scheduled for Wednesday morning, March 18, from 9:00 to 11:30 a.m. These will consist of discussions of pipe line problems. In order to generate more participation, a number of small groups will be formed with discussion leaders for each. An effort will be made to limit the size of each group to about 40 people and provide sufficient groups to accommodate everyone.

Mr. Doremus will conduct the Cathodic Protection Symposium at 9:00 to 11:30 a.m. Thursday morning, March 19.

Many, but not all, back issues of Corrosion are available for sale.



OFFICIALS OF PIPE LINE PROGRAM at 1953 Chicago NACE Conference: (Left to right) M. C. Callahan, Tulsa Pipe Line Division, Gulf Refining Co., Tulsa, Okla.; E. R. Lopez, Barrett Division, Allied Chemical & Dye Corp., New York; E. P. Doremus, Cathodic Protection Service, Houston; A. L. Stegner, Tennessee Gas Transmission Co., Houston.

### Pipe Line Coatings Discussion Leaders Named by E. R. Lopez

Discussion leaders for the Pipe Line Coatings Session to be held at Chicago in March during the Ninth Annual NACE Conference and Exhibition at Hotel Sherman have been named as follows by E. R. Lopez, session chairman, of Barrett Division, Allied Chemical & Dye Corp.:

For General Construction Contractors—Ray L. Smith, Ray L. Smith & Son, El Dorado, Ark.

For Coating Equipment Manufacturers—R. E. Shackleford, Parrault Equipment Co., Tulsa, Okla.

For Consulting Engineers—Hugh L. Hamilton, A. V. Smith Co., Bala-Cynwyd, Pa.

For Pipeline Owners—A. D. Simpson, Jr., United Gas Corp., Houston, Texas.

For Factory Coating Applicators—M. M. Bowen, Hill, Hubbell & Co., Di-

vision, General Paint Corp., Cleveland.

For Coal Tar Coating Manufacturers—W. F. Fair, Jr., Koppers Co., Westfield, N. J.

For Asphalt Coating Manufacturers—Wayne E. Broyles, Brance-Krachy Co., Inc., Houston.

For Petroleum Base Coating Manufacturers—Wayne E. Schultz, Dearborn Chemical Co., Chicago.

For Asbestos Felt Manufacturers—E. J. Liggett, Johns-Manville Sales Corp., Tulsa.

For Glass Wrapper Manufacturers—R. W. Farriss, Owens-Corning Fiberglass Co., Newark, Ohio.

Following brief remarks by each, time will be provided for questions from the floor.

### Underground Cable and Feedwater Corrosion Are Symposium Topics

Information significant to engineers concerned with protection of underground cable installations and water handling equipment in steam-electric power plants is included in the four papers to be given at the Electrical and Communications Symposium during the NACE 1953 Conference at Chicago. The symposium will be held from 2 to 4:15 p.m. Wednesday, March 18 at the Sherman Hotel, conference headquarters.

Problems incident to the protection of a copper-jacketed telephone cable buried in the general area of the bed of a salt lake are discussed in one paper. Studies leading to a decision to install magnesium anodes as a protective measure are reviewed.

A second paper covers application of a magnetic amplifier in a controlled rectifier for the cathodic protection of underground metallic structures. Information of interest to engineers concerned with installations in urban areas from which ground-return trolley car routes are being eliminated is presented. The resulting development, as a consequence of eliminating the ground-return circuits, of a large number of unsatisfactory electrolysis conditions prompted the author of this paper to design and use a magnetic amplifier to provide continuous control of rectifier output. Details of an experimental installation will be given and advantages of this amplifier.

(Continued on Page 26)

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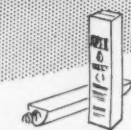
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Against the oleic acid, the resistance and performance of TYGON, in any of its forms, depends primarily upon the concentration of the acid and the service temperatures involved. At low acid concentrations and low temperatures, the resistance and performance of TYGON are excellent. However, as concentration or temperature increase, definite changes take place. If both are increased, the apparent limits are full concentration at 125°F. Beyond this point, the protectability of TYGON is relatively unaffected, but physical changes limit its performance. Pronounced hardening and stiffening gradually take place, along with a noticeable color change. Thus, at high temperatures, the effi-

ciency of TYGON is reduced with time and concentration.

Where mixtures of oleic acid and other chemicals are encountered, the resistance of TYGON varies according to the nature of the other chemicals present. It is difficult to estimate the degree of protection offered, without full knowledge of the existent conditions. Previous testing or the counsel of U. S. Stoneware engineers is strongly recommended.

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# Six High Temperature Corrosion Papers on Program

## Rutherford Points to Significant Material

The American drive to manufacture new products and reduce the cost of manufacturing products generally has made careful consideration of high temperature corrosion essential, John J. B. Rutherford, of Tubular Products Division, The Babcock and Wilcox Company, Beaver Falls, Pa. believes, Mr. Rutherford, chairman of the NACE Symposium on Corrosion at Elevated Temperatures to be presented 9 to 12 noon March 18 during the Ninth Annual NACE Conference and Exhibition in Chicago, has arranged tentatively for presentation of six papers in this symposium. The papers, he said, will assist engineers in selecting materials for chemical processing and power generation plants, and cover a variety of subjects.

Papers tentatively scheduled are:

Oxidation of Numerous Iron and Steel Compositions at 1300 Degrees F by J. A. Cameron. This paper is designed to interest builders of heavy machinery for operation at high temperatures. Information on oxidation tests extended to 4000 hours involving ductile, alloyed and cast irons and steels and wrought steel is included.

Some Notes on the Oxidation Resistance of Boron-Containing Chromium-Nickel-Cobalt-Iron Alloys by W. O. Binder and E. D. Weisert. In some jet turbine alloys boron is useful as a strengthening element but is sometimes detrimental to surface stability. The oxidation tests in the range 1850 to 2000 degrees F demonstrate that by proper control of composition boron-bearing alloys may be designed which have oxidation resistance comparable to alloys without boron.

Corrosion by Aqueous Solutions at Elevated Temperatures and Pressures by F. H. Beck and M. G. Fontana. Structural materials suitable for operation at higher temperatures and pressures are demanded by the chemical industry. Data obtained at atmospheric pressures are in many cases misleading. This paper describes tests on stainless steels, irons, nickel, titanium and other metals at 425 degrees F in solutions of nitric, phosphoric, acetic and sulfuric acids and sodium hydroxide.

Porcelain Enamels and Ceramic Coatings—Prime Inhibitors of Metal Corrosion by D. G. Bennett. Some of the pertinent background of current developments in protecting metal from corrosion with ceramic coatings is reviewed. Test methods are given and evaluation of selected tests discussed. Some examples of coating effectiveness and areas in which coatings may be used to advantage are presented.

High Temperature Lead Corrosion of Stressed Steel by H. F. Peters. Sudden failure of wrought steel kettles used in the temperature range 1000-1200 degrees F led to a laboratory investigation. Effect of lead bath composition, stress, temperature and microstructure on corrosion and stress-rupture life of rimmed and silicon killed steel specimens is reported.

An investigation of Accelerated Oxidation Due to Vanadium by F. C.

Monkman and N. J. Grant. Additional information has been obtained on the effect of additives to reduce the corrosiveness of vanadium oil ash. This has become a significant problem in the operation of heating furnaces, power boilers and gas turbines.

## Five Papers Listed For Protective Coatings Symposium at Chicago

The five papers readied for presentation during the Protective Coatings Symposium during the NACE Chicago Conference from 9 to 11:30 am Friday, March 20 at Hotel Sherman cover a variety of subjects in the coating field.

Papers scheduled are as follows:

Coating Research and Applications in Atomic Energy Operations by C. D. Watson. This paper includes information recently declassified by the Atomic Energy Commission. The manner in which the AEC is using coatings is expected to be interesting.

Field Tests of Exterior Coatings for a Pipeline Conveying Fuel Oil Heated to 200 Degrees F by E. R. Stauffacher and R. R. Davidson, relates field tests and experience in selection of protective coatings for 41 miles of 8-inch schedule 30 pipe. Tests include application of external pressure at predetermined locations, electrical resistance measurements and cold bends. Final data and conclusions will be presented.

Filiform Corrosion by Maurice Van Loo, presents a theoretical explanation of this type of corrosion and is illustrated with time-lapse motion photography. Filiform corrosion apparently has no direct relationship with the metallurgical pattern of the surface, light, biological activity of inhibitive pigments. The directing force is explained on the basis of concentration cells.

Effects of the composition of Steel on the Performance of Organic Coatings in Atmospheric Exposure by F. L. LaQue and J. A. Boylan gives at least a partial answer to the question as to whether the improved atmospheric corrosion resistance of alloy steels is of any advantage when they are painted. Paint was a common pigmented baking alkyd primer with pigmented baking urea modified alkyd top coat automobile finish, with and without zinc phosphate pretreatment.

Weld Seams and Weld Flux Effects on Coating Life, by A. J. Liebman covers performance data important to corrosion engineers developed by the author.

## Advance Program

An advance program for the 1953 Conference and Exhibition is scheduled to be mailed to all members of the National Association of Corrosion Engineers before the middle of January. Additional copies of this program may be obtained by writing to NACE Central Office, 1061 M & M Building, Houston.

The program will list the tentative technical program, and outline in general the events of the March 16-20 meeting which will be held at the Sherman Hotel, Chicago. Names of exhibitors will be listed also.

## Papers on Corrosion Principles Summarized

A preliminary summary of the content of the four papers to be given during the Corrosion Principles Symposium 9 to 11 a.m., Tuesday, March 17 at Chicago during the Ninth Annual NACE Conference and Exhibition has been given by J. V. Petrocelli, chairman of the symposium. The symposium, like other events on the conference calendar, will be held at Hotel Sherman.

Prof. Andre J. de Bethune of Boston College, Chestnut Hill, Mass., will present a paper on the fundamental concepts of electrode potentials, including standard potentials.

Prof. Norman Hackerman of University of Texas, Austin will speak on the measurement of potentials, including reference electrodes.

Dr. Morris Cohen, National Research Council, Ottawa, Canada will give a paper on the interpretation and significance of potential data in corrosion.

Dr. Thomas P. May, The International Nickel Co., Inc., New York will talk also on the significance and interpretation of potential data.

## Underground Cable—

(Continued From Page 24)

fier over other available control devices will be listed.

A third paper dealing generally with underground cables is intended to bring up to date continued studies and the latest experiences with compounded Neoprene as a corrosion preventive covering for metallic sheaths. History of the thermosetting coverings for underground cables will be reviewed.

Corrosion in the feedwater systems of power plants will be covered in the fourth paper. Emphasis will be on the selection of materials, especially for feed pumps in combating the corrosion-erosion phenomena so prevalent in the high temperature and pressure steam generating systems of the power industry. Studies comparing the relative service life of carbon steel and alloy steel equipment will be given.

## Boron Brightens Alloy Shortage Prospect

Developments in the use of boron as a powerful constituent of engineering and mechanical steels have brightened the prospects for an adequate supply of alloys for the makers and users of steel, according to the 80-page book "Boron Steel," published by the American Society for Metals, 7301 Euclid Ave., Cleveland 1, Ohio.

According to the book, the use of boron has increased five-fold in a period of two years. Use of boron amplifies the effect of alloying elements, lessening the amount of the element needed to give required results. Not only does this ease the shortage of alloying elements, but the equivalent boron steel is very often cheaper than the conventional types of steel, it is said.





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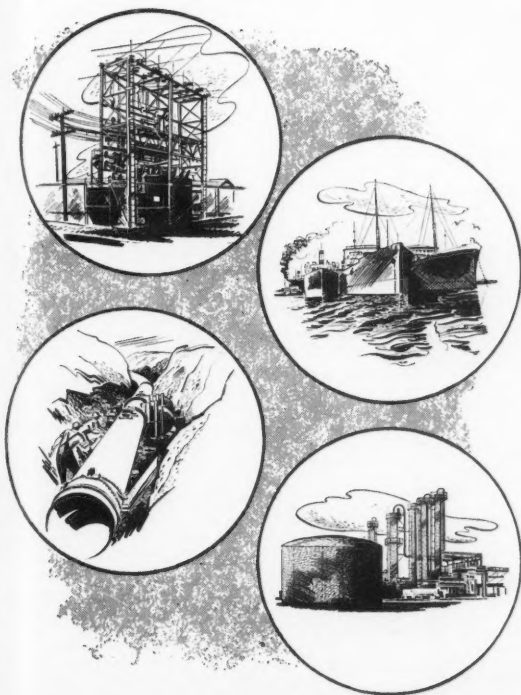
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## 2 Sessions Set for Chemical Industry Symposium

Two sessions will be held for the presentation of eight papers in the Chemical Industry Symposium at the Chicago Conference of the National Association of Corrosion Engineers in March. They will be held from 2 to 4:15 p.m. Thursday, March 19 and from 9 to 11:30 a.m. Friday, March 20.

The papers scheduled are as follows: Effects of Structures and Phases on Corrosion of Steel by F. A. Prange, Phillips Petroleum Co., Bartlesville, Okla. This is a discussion of corrosion problems from the metallurgist's viewpoint and includes comments on the metallurgical structure of carbon and alloy steels and their corrosion resistance.

Corrosion by Acids at High Temperatures by R. F. Miller, R. S. Treseder and A. Wachter, Shell Development Co., Emeryville, Cal. deals with corrosion data for various alloys exposed to a number of acids. It also describes a method of obtaining corrosion data with acids and other media above their normal boiling points.

The Use of All-Plastic Piping and Equipment in Technical Corrosion Protection by J. L. Huscher, Technical Director, American Agile Corp., Bedford, Ohio covers a new group of self-supporting materials that are finding increasingly widespread use in corrosion resistant installations.

The Behavior of Titanium in Sulfuric and Hydrochloric Acids by Warren W. Harple, Research Chemist, Allegheny Ludlum Steel Corp., Brackenridge, Pa. includes new data on the corrosion resistance of titanium, including information on sulfuric acid from 0 to 95 percent and hydrochloric acid from 0 to 37 percent at several temperatures.

Graphical Multiple Correlation of Corrosion Data by O. B. Ellis, Senior Research Engineer, Armco Steel Corp., Middletown, Ohio concerns a graphical method for multiple correlation analysis

of experiments having several variables. It presents a method of materially simplifying evaluation of corrosion data by statistical methods.

Resistance of Aluminum Alloys to Atmospheric Weathering by R. H. Brown and associates, Aluminum Company of America, New Kensington, Pa. gives results of atmospheric weathering tests of aluminum alloys. They were made under several types of atmospheric exposure conditions, including those containing industrial contaminants.

Corrosion Study in a Salt Plant by H. O. Teeple, The International Nickel Co., Inc., New York and another author to be named later will cover an extensive study of corrosion in a salt plant. The paper should be of interest to handlers of brine who are faced with salt corrosion problems.

A paper by James Collins of E. I. Du Pont de Nemours & Co., Wilmington, Del. will include information on some of the recent developments of this company in the corrosion field.

### Three Important Topics Outlined for Oil and Gas Industry Session

Three subjects important to the industry will be presented during the Oil and Gas Industry Symposium at the 1953 NACE Conference at Chicago. The symposium, to be held from 2 to 4:15 pm Wednesday, March 18, will consist of three papers: On Casing corrosion, inhibitor evaluation methods and sweet oil well corrosion.

Corrosion of Casing in Oil and Gas Wells by Jack L. Battle of Humble Oil and Refining Co., Houston, will summarize present understanding of the casing corrosion problem. The magnitude and complexity of the over-all prob-

lem is being summarized for the first time, and attention is called to several conditions which have gone virtually unrecognized for many years. Mr. Battle, chairman of NACE Technical Practices Committee —IH on Corrosion of Oil String Casing, has had the opportunity to study the experiences of a number of producers. He will discuss several known types of casing corrosion with respect to their economic significance, causation, preventive measures and investigation techniques.

Laboratory Methods for the Evaluation of Inhibitors for Use in Oil and Gas Wells, by E. C. Greco of United Gas Pipe Line Co., Shreveport, La., and J. C. Spaulding, Jr., Sun Oil Co., Dallas, is based on a survey of the methods employed by several oil producers and a number of chemical companies that manufacture inhibitors. Establishment of standards for evaluating inhibitors is a long sought goal of both consumer and supplier. The authors are chairman and co-chairman of a special subcommittee formed to determine if this goal can be attained. Significant in this paper will be a discussion of the correlations between laboratory experiment and field experience.

Corrosion in Sweet Oil Wells by H. E. Greenwell of Atlantic Refining Co., Dallas explains recent progress in studies of sweet oil well corrosion problems. Data included is that collected by NACE Technical Practices Committee 1-C on Sweet Oil Well Corrosion. During the last several months efforts have been directed toward defining more specifically the corrosion problems of low pressure wells. Incidence of corrosion in these wells has been found to be related to water production, and this fact suggests means to anticipate development of corrosion and gain control before damage occurs. Mr. Greenwell is vice-chairman of TP-1C.

### Better Packing Urged To Limit Corrosion

Better methods of packing and marking shipments are a necessity if machinery shipments are to arrive in good condition, according to officials of the American Association of Machinery Importers, Inc. It was pointed out that too often, merchandise arrives in the United States in a damaged or rusty condition.

In spite of the fact that shipping companies recommend certain methods of packing, each manufacturer has a different manner of packing so that no standard methods exist. Shippers say standards should be established for rust-proofing, marking and constructing packing cases.

While not many executives are familiar with the actual mechanics involved in handling freight, rising damage costs may make it mandatory they acquaint themselves with the problem, it was stated. One British shipping firm has compiled a packing check list in which several lines are allotted for description of the rust proofing methods employed.

Persons interested in joining NACE may get information and application blanks for membership by writing to Central Office, 1061 M & M Building, Houston 2, Texas.

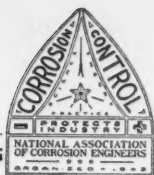
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# Corrosion Abstracts

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• **NOTE:** For further information on the *NACE Abstract Filing Index* see December, 1952 issue of *Corrosion. Industries in the groups coded under 8 are listed in this issue.*

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## 2. TESTING

### 2.6 Preparation and Cleaning of Specimens

2.6 Adsorption of Water Vapor on Solid Surfaces. E. P. BOWDEN AND W. R. THROSELL. *Nature*, 167, No. 4250, 601-602 (1951) Apr. 14.

Adsorption of water vapor on metal surfaces was determined by measuring on a microbalance the increase in weight of metal foils when water vapor was admitted. The results suggest that the heavy adsorption is spurious and is due to contaminants on the surface. Foils of gold and platinum cleaned by degreasing solvents do not always exhibit it. When heavy adsorption does occur, it can be eliminated by drastic heating of the metal during the preliminary evacuation. Curves showing the adsorption of platinum foil cleaned, but not specially heated, and after it had been raised to a red heat by electronic bombardment, are given. No heavy adsorption was observed, even when the pressure of water vapor was 90-95 percent of saturation. 7 references.—INCO.

## 3. CHARACTERISTIC CORROSION PHENOMENA

### 3.5 Physical and Mechanical Effects

3.5.9, 2.1.1, 6.2.2

Reactions in the Solid State in Oxide Films Formed on Iron. (In French.) EARL A. GULBRANSEN. *Rev. met.*, 48, 337-352 (1951) May.

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AER—Aeronautical Engineering Review, Institute of Aeronautical Sciences, Inc. 2 East 64th St., New York 21, N. Y.

ALL—The Abstract Bulletin, Aluminum Laboratories, Ltd. P. O. Box 84, Kingston, Ontario, Canada.

AWWA—Journal, American Water Works Association. Amer. Water Works Assoc., 521 Fifth Ave., New York 17, N. Y.

BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

BTR—Battelle Technical Review, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio.

BNF—Bulletin; British Non-Ferrous Metals Research Association, 81-91 Euston St., London NW 1, England.

CALCO—Calco Chemical Division, American Cyanamid Corp. Bound Brook, New Jersey.

CE—Chemical Engineering, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

CEC—Consolidated Edition Co. of New York, Inc. 4 Irving Place, New York 3, New York.

EL—Electroplating, 83/85 Udney Park Road, Teddington, Middlesex, England.

EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

GPC—General Petroleum Corp. of California, 2525 East 37th St., Los Angeles 11, Calif.

INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.

IP—Institute of Petroleum, 26 Portland Place, London W#1, England.

MA—Metallurgical Abstracts, Institute of Metals, London, England. 4 Grosvenor Gardens, London SW 1, England.

MI—Metallurgia Italiana. Associazione Italiana di Metallurgia. Via S. Paola, 10, Milano, Italia.

MR—Metals Review, American Society of Metals. 7301 Euclid Ave., Cleveland 3, Ohio.

NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.

NBS—National Bureau of Standards. Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.

NSA—Nuclear Science Abstracts, United States Atomic Energy Commission, Technical Information Division, Oak Ridge, Tenn.

PDA—Prevention Deterioration Abstracts. National Research Council, 2101 Constitution Ave., Washington 25, D. C.

RA—Refrigeration Abstracts, American Society of Refrigeration Engineers. 40 West 40th St., New York 18, N. Y.

RM—Revue de Metallurgie, Paris, France. 5 Cite Pigalle, Paris (9e), France.

RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London. Waldegrave Rd., Teddington, Middlesex.

TIME—Transactions of Institute of Marine Engineers. 85 The Minories, London EC 3, England.

UOP—Universal Oil Products, 310 South Michigan Ave., Chicago, Illinois.

ZDA—Zinc Development Association. Lincoln House, Turl Street, Oxford, England.



temperatures is proposed as a new way to study the above. Thermodynamic calculations were made for 5 types of gas-solid reactions. Shows that in the solid phase, the higher oxides and iron form ferrous oxide at 570-700°C. The kinetics are studied in detail. The formation of ferrous ferric oxide is studied, as are also relationships between the two oxides. Data are charted and graphed. Photomicrographs. 29 references.—BLR.

### 3.5.9, 2.3.9, 6.2.2

**Kinetics and Mechanism of Solid Phase Reactions in Oxide Films on Pure Iron.** E. A. GULBRANSEN AND R. RUKA. *Ind. & Eng. Chem.*, 43, No. 3, 697-703 (1951) March.

The composition of the oxide film formed on iron above 570°C has been in doubt, since results obtained by electron diffraction did not agree with X-ray diffraction or micrographic data. Thermodynamic calculations and electron diffraction studies have resolved the conflict and enabled the authors to suggest a mechanism for the oxidation reaction.—BNF.

### 3.5.9, 2.3.9, 6.3.4

**The Kinetics of the Oxidation of Cobalt.** EARL A. GULBRANSEN AND KENNETH F. ANDREW. *J. Electrochem. Soc.*, 98, 241-251 (1951) June.

The vacuum-microbalance method was used to study the effect of time, temperature, pressure, pretreatment, etc., on rate of the reaction below 700°C. The rate data are interpreted in terms of the transition-state theory and calculated energy and entropy of activation for the reaction. An alternate mechanism to that proposed by Valensi is suggested to account for the reaction  $\text{Co}_2\text{O}_3 + \text{Co} \rightarrow 4\text{CoO}$ . 25 references.—MR.

### 3.5.9, 6.2.3, 8.4.3

**Effect of Temperature on Carbon Steel in Refinery Vessels Being Surveyed.** V. B. GUTHRIE. *Petroleum Processing*, 6, No. 7, 719-721 (1951) July.

Study of the deterioration of metal at high temperatures over extended periods. The metals in which graphitization has been found are mostly low carbon and carbon-molybdenum steels. It is most likely to occur in those refinery units, such as catalytic or thermal cracking plants, where temperatures of over 900°F are encountered. Carbon steel reactors with integrally bonded liners of 18-8 showed graphitization. Graphitization in the heat affected zone near welds may result in planes of weakness in the metal if the graphite is in chain form, or connected nodules along the grain boundaries. Graphite may be caused by residual aluminum due to killing of steel and cold working. Some companies are considering the use of 1 chromium-0.5 molybdenum alloy steel for service at temperatures over 800°F, while others are going to use carbon steel either bare or with internal insulating liners.—INCO.

## 3.6 Electrochemical Effects

### 3.6.5, 3.8.3

**The Induction Period in the Displacement of Copper from its Solutions by Passivated Iron.** (In Russian.) I. V. KROTOV. *Doklady Akad. Nauk S.S.S.R.* (Reports Acad. Sci. USSR), 76, No. 4, 559-562 (1951) Feb. 1.

Oxide films were formed on iron by heating at 475°-485°C. in air for a few

seconds; the specimens were then immersed in acid copper sulfate solution. The effects on the induction period of film thickness, copper sulfate and sulfuric acid concentration, and time of heating, were studied.—BNF.

### 3.6.5, 5.4.5, 4.6.11

**Blistering Phenomena of Paints in Marine Environments.** W. G. O'DRISCOLL. *J. Iron Steel Inst.*, 167, 353-357 (1951) Apr.

Investigation of the blistering of chlorinated-rubber-based paints, applied to mild-steel panels, immersed in 0.5 normal sodium chloride demonstrated the presence of electrolytes within the blisters. The anodic or cathodic origin of the blisters is illustrated by potential plots over a blistered surface using a silver chloride electrode. Mechanism of blistering of paints on a steel surface immersed in sea water is discussed.—BLR.

### 3.6.5, 5.9.4, 3.7.4, 6.3.8

(1) Anodic Corrosion of Lead in  $\text{H}_2\text{SO}_4$  Solutions. (2) Some Preliminary Studies of Positive Grid Corrosion in the Lead-Acid Cell. J. J. LANDER. *J. Electrochem. Soc.*, 98, No. 6, 213-219; 220-224 (1951) June.

(1) Pure lead was anodized at various constant potentials in  $\text{H}_2\text{SO}_4$  solutions. At potentials below those for  $\text{PbO}_2$  formation, a layer of tetragonal  $\text{PbO}$  is formed near the Pb.  $\text{PbSO}_4$  is formed as an outer layer. The rate of corrosion of lead was found to increase with increasing temperature and decreasing acid concentration.

(2) Grid growth appears to be proportional to the depth of corrosion after an initial period. Electrolyte concentration and cycle time are shown to be important facts in the corrosion process under constant-concentration conditions. These effects are discussed in terms of a cycling cell.

### 3.6.5, 6.3.11

**The Electrochemical Characterization of Corrosion and Other Reactions in Metal-Solution Systems; The Potential-pH Diagram of the Silver-Solution System According to M. Pourbaix.** (In German.) KURT NAGEL. *Z. Elektrochem.*, 55, 144-145 (1951) Mar.

Discusses theoretically ion exchange in the Ag-solution system in relation to pressure and concentration.—MR.

### 3.6.6

**Bimetallic Corrosion.** M. E. PARKER. *Oil Gas J.*, 50, No. 13, 81 (1951) Aug. 2.

Discussion of the failure of the electromotive series to explain all the instances of occurrence and nonoccurrence of galvanic action.—INCO.

### 3.6.8

**Investigation of the Process of Passivation of Iron in the System  $\text{HNO}_3\text{-H}_2\text{SO}_4\text{-H}_2\text{O}$ .** (In Russian.) I. OKNIN. *J. Applied Chem. U.S.S.R.* (Zhurnal Prikladnoi Khimii), 24, 61-73 (1951) Jan.

Experimental investigation of the above showed that passivation of a self-soluble metal occurs when the maximum rate of the high-potential cathode process in an oxidizing reaction medium (maximum cathode current density) exceeds the maximum rate of the low-potential, active anode process (maximum anodic current density). Mechanisms of anodic polarization are proposed for solution of different compositions. Method of investigation is described. Data are tabulated. Results are discussed in detail. 42 references.—BLR.

### 3.6.8

**Structure of the Electrocapillary Double Layer and the Over-Voltage of Electrolytic Reactions.** *Nature*, 167, 613-614 (1951) Apr. 14.

Companion notes by J. van Cakenberghe, and by N. K. Adam, E. W. Balson, and F. D. Hills, discuss experimental results obtained by each group of workers and their theoretical interpretation.—BLR.

### 3.6.8

**Studies on Anodic and Cathodic Polarization of Metals.** (In German.) R. PRONTELLI. *Z. Elektrochem.*, 55, 128-143 (1951) Mar.

Summarizes theoretical and experimental research results on the electrochemical behavior of metals obtained by the author's organization during the past year. Includes diagrams and tables. 58 references.—BLR.

### 3.6.8, 3.6.5

**Theoretical Study of Overvoltage in Oxidation-Reduction Systems.** (In French.) EUGENE LEWARTOWICZ. *Comptes rend.*, 232, 1207-1209 (1951) Mar. 19.

The ferrous-ferric system was studied theoretically as an example of the above.—BLR.

### 3.6.8, 6.8.2

**Development of Electrical Potentials of Zinc-Aluminum Alloys in Acid Electrolytes.** (In German.) GEORG MASING AND GISELA MOLDEHNKE-HOHMANN. *Z. Metallkunde*, 42, 19-23 (1951) Jan.

Describes a systematic study of the effect of pure aluminum on the zinc potential in acid 0.5 normal sodium chloride solutions. Changes in potentials of pure zinc and pure aluminum, as well as the fact that the potential of a mechanical mixture is determined by the nobler component, are explained by the very strong polarizability of zinc-rich solid solution. Oxygen in the electrolyte was found to greatly reduce the polarizability of the electrode. Tables and graphs.—BLR.

### 3.6.9, 5.2.1

**Corrosion by Stray Currents.** N. P. PEIFER. *Manufacturers Light & Heat Co. Am. Gas Assoc. Monthly*, 33, No. 2, 24-26 (1951) Feb.

Stray currents from street railway and mine haulage systems once considered as detrimental to underground pipe systems are now recognized by corrosion engineers as a source of free cathodic protection and are being used as such. A properly engineered mitigation system will provide the path for the returning electric currents by the use of a current removal wire connecting the pipelines to negative side of generator. Additional protection to the pipelines is secured by the simple installation of a resistor between the rails and the negative terminal of the generator.—INCO.

## 3.7 Metallurgical Effects

### 3.7.3, 3.4.6

**Theory of the Scaling Process for Alloys.** (In German.) K. HAUFFE. *Metallüberfläche* (Ausgabe A.) 5, No. 1, A1-A7 (1951) Jan.

Considers the mechanism of scaling mathematically and diagrammatically; distinguishes two types, according to whether conduction in the layer of scale is electronic or ionic; examples treated are the reactions of several silver alloys with bromine vapor, and the oxidation of zinc and its alloys and of nickel and copper alloys.—BNF

## 3.7.3, 3.5.9, 3.7.4

**Application of Wagner's Theory of Scaling in the Development of Heat-Resistant Alloys.** (In German.) KARL HAUFFE. *Z. Metallkunde*, 42, 34-43 (1951) Feb.

Shows that Wagner-Schottky's hole-formation theory and Wagner's work on the scaling of pure metals and alloys can be directly applied to development of scaling alloys (not including alloys with precious metals). The problem, in general, is to select the components of the alloy in such a manner that the concentration of disturbance centers in the lattice and the mobility of ions are reduced. Includes graphs and tables. 62 references. —BLR.

## 3.7.3, 6.2.5

**How to Get Better Welding Results With 17% Chromium Stainless.** T. A. PRUGER. *Steel Horizons*, 13, No. 3, 10-12 (1951).

One possible substitute for chromium-nickel or austenitic stainless steels is Type 430 or 17 percent chromium stainless. Its main drawback is low ductility after welding, possible added costs of fabrication, and lower corrosion resistance as compared with austenitic grades. Presents results of experiments on effects of various heat treatments on ductility, also of atmospheric weathering and laboratory corrosion tests, on this material. Recommended arc welding and heat-treating procedures are outlined. Data are tabulated and microstructures illustrated. —BLR.

## 3.7.3, 6.2.5

**Welding and Its Effect on the Corrosion Resistance of Stainless Steel.** E. W. HOPPER. *Crucible Steel Co. of Amer. Paper before 7th Western Metal Congress*, Oakland, Cal., March 19-23, 1951. *Welding J.*, 30, No. 6, 503-507 (1951) June.

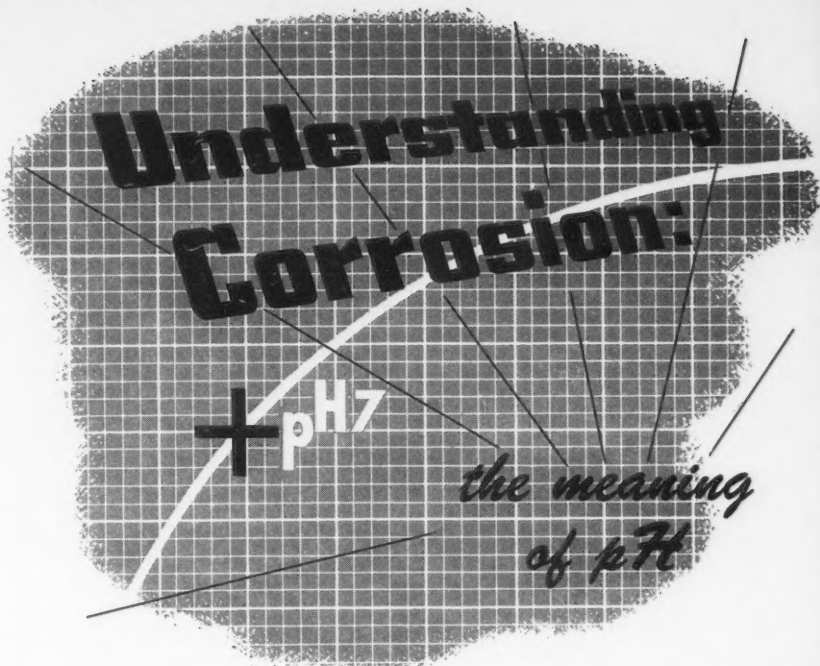
Most of the austenitic stainless steels cannot be stabilized with niobium because of the shortage of this metal and so the steels suffer from intergranular corrosion after welding. If properly annealed stainless steel with normal carbon content (types 304 and 316) is welded so that the steel is in the sensitizing temperature range of 1500-900°F less than 2 minutes, no serious loss of corrosion resistance in the weld zone is likely to occur. The most effective cooling medium is water either sprayed or swabbed on the weld area. Photomicrographs.—INCO.

## 3.7.4, 6.4.2, 3.7.3

**Forms and Methods of Corrosive Attack on Aluminum Alloys. I. Binary Cast Alloys. II. Effect of Rolling & Heat Treating on the Behavior of an Alloy.** (In German.) HANS KOSTRON. *Z. Metallkunde*, 42, 107-110, 133, 137 (1951) April, May.

Part I. Corrosion of cast binary alloys is largely determined by the solution potential resulting from grain segregation. The untreated casting is subject to both grain-boundary and internal-grain corrosion. Both heterogenizing and homogenizing processes were found to have destructive effects.

Part II. Rolling of an Al-Cu-Mg alloy was found to convert selective grain-boundary corrosion of the cast alloy into more diffuse or stratified corrosion, depending on degree of rolling, while intercrystalline forms of corrosion may occur in rolled and heat-treated alloys. Photomicrographs and charts.



A governing factor in establishing the rate and extent of corrosive attack of a solution on metal is the determinant of acidity or alkalinity — hydrogen-ion activity. This factor is identified by the symbol pH and measured on a scale on which readings of less than pH 7 indicate acidity and more than pH 7, alkalinity. Intensity either of acidity or alkalinity exerts a primary influence on the tendency toward corrosion, with severity of corrosive attack at its greatest in the acid zone and generally decreasing as alkalinity increases. Variations in pH further alter the degree of influence of other factors in corrosion. The nature of corrosion products, for example, may be affected, thus changing the character of the resulting protective film and rendering such a film formed in the neutral or alkaline zone more effective than one formed in the acid zone.

Consideration of pH as it affects and is affected by other determining factors is essential to proper evaluation of any corrosion problem. Understanding and assessing the relative importance of this and of all factors involved is Dampney's first approach to a preventive or corrective program — an approach that forecasts with exceptional accuracy the ultimate success of the coating system selected.

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## 3.7.3, 8.4.3, 3.2.2

The Significance of Metallurgical Factors in the Corrosion of Oil Refining Equipment. M. PRUNE, B. LE BOUCHER, AND P. LACOMBE. *Rev. inst. franc. petrole et Ann. combustibles liquides*, 6, No. 5, 145-155 (1951) May.

The corrosion of oil refining equipment may be traced to three principal factors: chemical, physical, and metallurgical. The last of these furnishes a means for investigating the reaction of different metals to the attacking chemicals by metallographic method. Studies have been made on the metals most frequently used in refinery equipment, viz., ordinary steel, brass, monel, and stainless steel. The results obtained on the steels and on the monel-metal (all of which were welded

pieces) showed the region of maximum corrosion to occur near the weld and hence to be attributable to local differences in composition. In the case of brass the corrosion was due to local dezincification as the result of contact with condensation water. These findings imply that the controlled composition of the metal by the addition of stabilizing agents is a prime method for preventing corrosion.—TDD.

## 3.7.4, 2.3.5, 5.9.4

Variation of Rate of Anodic Oxidation With Orientation of the Crystal Face. (In French.) JEAN HERENGUEL AND PIERRE LÉLONG. *Compt. rend.*, 232, 2218-2220 (1951) June 11.

Above was studied using an aluminum alloy.—BLR.

## 4. CORROSIVE ENVIRONMENTS

## 4.4 Chemicals Inorganic

## 4.4.5, 6.2.5, 6.4.2

Corrosion in Aqueous and Alcoholic Aerosol Systems. H. M. PARMALEE AND R. C. DOWNING. *Proceeding of the Chemical Specialties Manufacturers Association*, 45, 47-51, December 1950.

To detect the possibilities of cosmetic formulations contaminating alcohol or aerosol systems, a program of corrosion testing was started. High pressure glass tubes containing steel or aluminum test pieces and mixtures of 60 percent by weight propellant and 40 percent alcohol or water were stored in ovens 60 days at 130 degrees F (60 degrees C). Six different propellants, e.g., Freons 114, 22, 12 and 11 and  $\text{MeCHF}_2$  [difluoro ethane (1,1)] and  $\text{MeCClF}_2$  [difluoro-2-chloroethane (1,2)] were tested. The results in 10 different systems containing water and dilute or anhydrous alcohol with or without air are given. Corrosion in systems containing water or alcohol varies with the metal and propellant used. Differences in propellants do not follow the same order for different combinations of water, alcohol and air, although the stability of compounds of the type Freon-11 was generally low. For steel: 1) With water and 90 percent iso-propyl alcohol, air caused an increase in corrosion, but had little effect on systems containing anhydrous alcohols; air was undesirable with 90 percent ethyl alcohol. 2) Either with or without air, tests showed little difference between ethyl alcohol and isopropyl alcohol (anhydrous or 90 percent). 3) Aqueous systems were more corrosive than anhydrous or 90 percent alcohols. 4) Dilute alcohols were more corrosive than anhydrous. For aluminum: 1) There was a likelihood of vigorous reaction with anhydrous alcohols, particularly with less stable propellants. 2) Air had no effect on the tests. 3) Iso-propyl alcohol was generally less corrosive than ethyl alcohol. 4) In tests where vigorous reaction did not occur, anhydrous alcohols were generally less corrosive than water or 90 percent alcohols.—ALL.

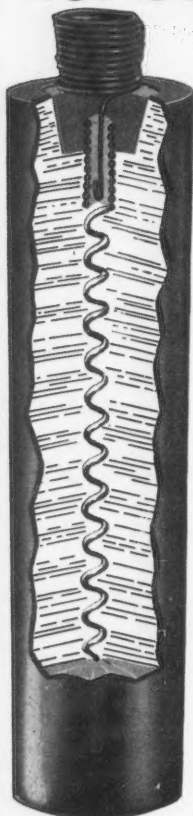
## 4.4.6, 6.1

Corrosion Forum—Construction Materials vs. Hydrocarbon Solvents. M. M. HOOVER. *Chem. Eng.*, 58, No. 6, 220, 222, 224; No. 7, 222, 224, 226-228, 230 (1951) June, July.

Papers include:

- 1) "Durimet 20" by W. A. Luce (Duriron Co.)
- 2) "Aluminum" by W. P. Colman & W. W. Binger (ALCOA).
- 3) "Carbon and Graphite" by W. W. Palmquist (Nat. Carbon Co.)
- 4) "Coatings" by K. Tator (Kenneth Tator Assoc.)
- 5) "Silicones" by J. A. McHard & L. Van Volkinburg (Dow Corning Corp.)
- 6) "Tatalum" by L. R. Scribner (Fansteel Metallurgical Corp.)
- 7) "Hastelloy" by E. D. Weisert (Haynes Stellite Co.)
- 8) "Lead" by K. H. Roll (Lead Inds. Assoc.)
- 9) "Chlorimets" by W. A. Luce (Duriron Co.)
- 10) "Cements" by R. B. Seymour (Atlas Mineral Prod. Co.)
- 11) "Glass Lining" by S. W. McCann (Pfauddler Co.)
- 12) "Stainless Steel" by G. L. Snair, Jr. (Allegheny Ludlum Steel Corp.)

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#### 4.6 Water and Steam

##### 4.6.4, 5.8.2

**Chemical Conditioning of Cooling Waters.** JOHN P. KLEBER. *Calgon, Inc. Combustion*, 22, No. 11, 45 (1951) May.

Threshold treatment of once-through and recirculating cooling waters is discussed and comparison is made between this internal method and external treatment of makeup water for cooling towers. Emphasis is placed on the capability of sodium hexametaphosphate, used in the threshold treatment method, to stop scale formation by stabilizing the water and prevent corrosion by forming a protective film over metal surfaces in the water system.

A supplementary treatment, such as chlorine or a chlorophenate, is often used to control organic growths.—NALCO.

##### 4.6.6, 7.5.5, 5.3.2

**The Corrosion of Domestic Galvanized Hot-Water-Storage Tanks.** I. LAIRD NEWELL. *J. New England Water Works Assoc.*, 65, 71 (1951).

Conditions affecting the permanent value of galvanized tanks are considered. Excessive operating temperatures, presence of copper in the supply system, and bicarbonates and nitrates in the incoming water are the principal causes of corrosion. Several methods to reduce corrosive trouble are suggested. In the discussion, several cases are described.—A.W.W.A.

#### 5. PREVENTIVE MEASURES

##### 5.2 Cathodic Protection

###### 5.2.1

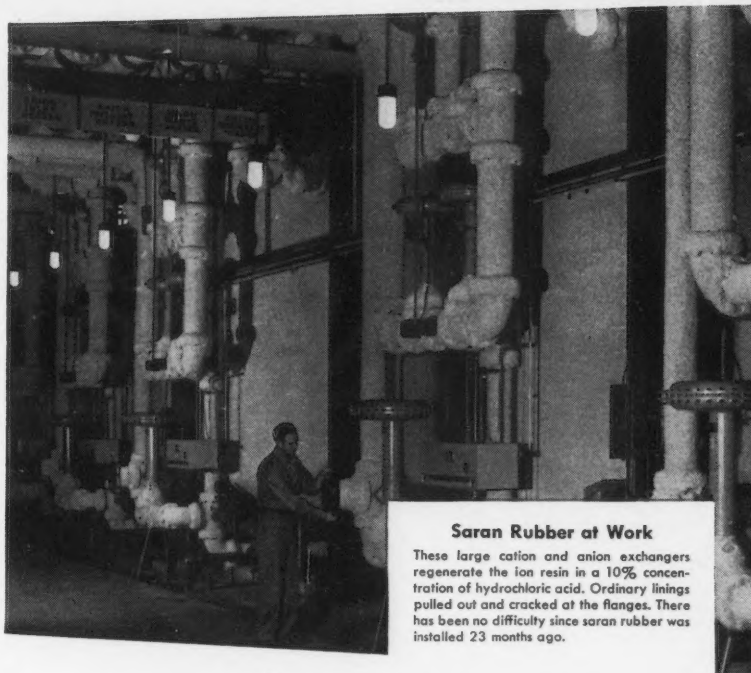
**Cathodic Protection Pays Off.** M. E. PARKER. *Oil & Gas J.*, 50, No. 1, 144 (1951) May 10.

Examples are presented of side-by-side, off-and-on, and fresh-start methods of comparing the total operating costs of similar structures with and without cathodic protection. In the particular examples chosen, cathodic protection was indicated to be more economical than other methods.

###### 5.2.1, 3.6.5

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Saran lined steel pipe—corrosion-resistant pipe that gives long-term operation with minimum maintenance.



**Cathodic Protection.** H. D. HOLLER. *J. Research Natl. Bur. Standards*, 47, No. 1, 1-6 (1951) July.

The paper outlines a procedure for determining current distribution over an electrode surface, as required in cathodic protection or in electroplating when the electrode potential bears a known relation to current density; and shows the relation of current distribution to resistance of current path and counter electromotive force. The primary current distribution (without polarization) is also computed. A method is suggested for determining the electrode potential-current density relation over an extensive surface in a uniform medium. In a nonuniform medium, the determination of current density by measurement of electrode potential becomes complex. In such a case the potential criterion of cathodic protection must be relied upon.—TDD.

#### 5.2.1, 3.6.9

**Cathodic Protection Technical Practices.** *Petroleum Engineer*, 23, D9-D12, D16, D18 (1951) July.

Describes application of cathodic protection and mitigation of electrolytic corrosion caused by stray current from cathodic protection systems. 56 references.—BLR.

#### 5.2.1, 8.9.3

**Impressed Current Ground Beds for Cathodic Protection.** A. W. PEABODY. Paper, Am. Gas Assoc. Distribution Conf., Memphis, April, 1951. *Gas*, 27, No. 7, 37-41 (1951) July.

The development and present practices pertaining to ground bed materials and construction methods, the effects of soil condition and anode configuration on ground bed performance, and some factors involved in selecting suitable sites and designing ground bed installations are discussed. Tests conducted by the N.A.C.E. committee on anodes for impressed currents are also described. This was a four-year program on the relative performance of carbon, graphite and steel anodes in various backfills.

#### 5.2.1, 8.9.3

**The Use and Abuse of Insulated Joints.** M. E. PARKER. *Oil Gas J.*, 49, No. 39, 70-72, 74-75, 77 (1951) Feb. 1.

Purposes of insulated joints used in combating underground corrosion and details of installations in the construction of pipe lines. Types of insulated joints, installation and testing techniques, location and application of insulated joints and hazards are discussed. Illustrations are given.—INCO.

#### 5.2.1, 8.9.3

**Current Requirements for Cathodic Protection.** M. E. PARKER. *Oil Gas J.*, 50, No. 5, 85 (1951) June 7.

How much current will be required to maintain a continuous negative charge to neutralize positive charges and prevent corrosion. Requirements for pipe lines in soil and bare pipe lines, and steel in contact with fresh and salt water are discussed.—INCO.

#### 5.2.2, 4.5.2, 8.9.3

**Magnesium Anodes Group.** M. E. PARKER. *Oil Gas J.*, 50, No. 3, 144 (1951) May 24.

The effects of the following factors in the design of magnesium anode groups are discussed: soil resistivity in the immediate vicinity of the anode; soil resistivity at greater depth; anode size; kind and amount of back-fill; spacing between

anodes; number of anodes in the group; potential of the cathode-distance of the anodes from the pipe line; and burial depth of the anodes.

#### 5.2.2, 8.9.3

**Full Protection of Coated Lines with Magnesium.** M. E. PARKER. *Oil Gas J.*, 50, No. 4, 119 (1951) May 31.

The installation of magnesium anodes for cathodic protection of pipe lines is described. Advantages of this means of protection include the feasibility of non-uniform distribution along a line to meet nonuniform demand; full cathodic protection to a line with lower total current due to distributed drainage; protection may be applied without reference to the location of power lines; the simpler installations involved do not ordinarily require right-of-way or easements; the design of a cathodic protection system may be modified in the field; and current drainage may be increased locally to meet unexpected demand increases. Disadvantages include higher cost per ampere-hour; operation at satisfactory current ratings only in low and medium resistivity soils; loss of protection during prolonged dry spells; more difficult supervision and maintenance.

#### 5.2.3, 8.9.3

**Corrosion and Its Control—Insulated Joints in Cathodic Protection.** M. E. PARKER. *Oil Gas J.*, 50, No. 9, 81 (1951) July 5.

Insulated joints serve to separate the protected structure from others which would impose an excessive drain on the system. Many types of insulation, as rubber tire sections, wood, or insulating materials, may be used. It is recommended that insulated joints be installed liberally on new pipe lines, and if they are not needed they can be short-circuited. When the joints are buried, 2 insulated #10 copper wire leads should be connected, and the connection well coated.—INCO.

### 5.4 Non-Metallic Coatings and Paints

#### 5.4.5

**Chemical Composition and Adsorptive Properties of Clear Films.** G. C. WILLIAMS. *Paint, Oil Chem. Rev.*, 113, No. 24, 124-127 (1950); *Official Digest Federation Paint and Varnish Production Clubs*, No. 311, 1020-1032 (1950).

Data are tabulated on the rate of oxidation (from ultimate microanalysis), carbon tetrachloride solution content and oleic acid sorption of 2 films of the material investigated by the Cincinnati Club.—RPI.

#### 5.4.5, 2.3.2

**Durable Organic Coatings.** B. F. AMES. *Ind. Finishing (U. S. A.)*, 27, No. 8, 52-54 (1951) June.

A short description of coatings which have been developed as a substitute for nickel plating on zinc alloy die castings and on steel pressings. The procedure recommended is to buff the zinc alloy or the steel to a high finish, flash-coat with bright zinc, passivate the surface and apply a luster finish which would simulate gold, chromium, brass or copper. The finishes have been subjected to accelerated weathering tests.—ZDA.

#### 5.4.5, 6.4.2

**Aluminum Paint.** *Farbe u. Lack*, 57, No. 1, 23-24 (1951).

A discussion of the formulation and

application of aluminum-pigmented paints. To maintain the covering power of the pigment on long storage, three alternatives are proposed: keeping powder and medium apart in the same container by means of a membrane; addition of a solution of rubber to a paint based on a low A.V. medium; use of a natural resin solution as medium, e.g., a 33-35 percent coumarone resin solution to which 18-20 percent of aluminum powder may be added. The properties of this latter type of paint are described in some detail. Since the color of the resin is not important, bitumen may be substituted for coumarone resin. For external iron work the paint is applied over a red lead primer; for protection of wood, a neutral plasticiser should be added.—RPI.

#### 5.4.5, 8.9.1

**Aircraft Finish Demonstrates Durability.** G. C. CLOSE. *Products Finishing (U.S.A.)*, 15, No. 9, 36 (1951) June.

A wing flap, broken loose and fallen into the Pacific five years ago, was taken from the water and found to be still in very good condition. The metallurgical condition of the metal was still excellent according to a Douglas Aircraft expert. Some cadmium-plated screws had suffered slight corrosion, and there was some galvanic corrosion at bi-metal contact but in general the finish system had not failed, even in areas where the flap had been severely dented by its fall. This finish, on 24ST Alclad, consisted of anodic treatment in chromic acid bath, a coating of zinc chromate primer, conforming to specification AN-P-656 and a top coat of AN-L-29 sky blue lacquer. In no area had the finish system permitted corrosion of the underlying metal.—ALL.

### 5.5 Oil and Grease Coatings

#### 5.5.1, 5.9.2

**The Nature and Use of Petroleum Base Rust Preventives.** HOWARD B. CARPENTER. Paper, Am. Soc. Lubrication Engrs., 6th Ann. Conv., Philadelphia, April 16-18, 1951. *Lubrication Eng.*, 7, 174-177 (1951) Aug.

The four principal types of petroleum base rust preventives are described: plastic, fluid, thin-film and solvent. Various typical uses are discussed such as, machinery during shipment and storage, spare parts, anti-friction bearings, hydraulic devices and systems, gear cases, turbines, power transmission devices, instruments, farm machinery, strip and sheet steel, parts in process, etc. Application and removal are covered.

#### 5.5.3

**Ersatz Sweat Fights Metal Corrosion.** *Business Week*, No. 1137, 50-52 (1951) June 16.

By studying the peculiarities of human perspiration, Socony-Vacuum researchers have been able to develop and improve slushing oils that neutralize or remove finger-prints before they cause damage to metal parts. The corrosion from a print can ruin finely made bearings, gears or piston rings in 24 hours. A synthetic perspiration is applied to different kinds of metal plates to get an over-all check on corrosion rates. Then the plates are given a filming treatment with standard and new slushing oils.—INCO.

#### 5.5.3

**Change of Elementary Composition of Oil Films Under Different Aging**

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**Conditions.** (In Russian.) A. YA. DRINBERG AND M. G. ROKHLIN. *Journal of Applied Physics* (Zhurnal Prikladnoi Khimii), 24, 220-222 (1951) Feb.

Detailed investigation showed that films based on pentaerythrate esters of acids of semidrying oils give the best corrosion protection and those based on tung oil, the worst. Influence of different conditions of aging during testing, on composition of oil films, was studied. Data are tabulated.—BLR.

### 5.5.3

**Protecting Iron From Atmospheric Corrosion by Oil Coatings.** (In Russian.) A. YA. DRINBERG AND M. G. ROKHLIN. *Journal of Applied Physics* (Zhurnal Prikladnoi Khimii), 24, 210-214 (1951) Feb.

Experiments are described on production of different oils and unpigmented coatings and testing them with respect to the above. Oils studied include tung oil, linseed oil and cottonseed oil. Effects of aging up to six months are investigated. Results are tabulated.—BLR.

### 5.5.3, 6.2.1

**Protecting Iron From Corrosion With Oil Coatings and Change of Physical Properties of the Latter During Aging.** (In Russian.) A. YA. DRINBERG AND M. G. ROKHLIN. *Journal of Applied Physics* (Zhurnal Prikladnoi Khimii), 24, 215-220 (1951) Feb.

Apparatus designed to simulate atmospheric conditions plus accelerated aging for study of corrosion-protection and physical properties of tung, linseed and cottonseed oils is described and illustrated. Data obtained by use of this apparatus are tabulated and charted.—BLR.

## 5.8 Inhibitors and Passivators

### 5.8.3

**Liquid Vapor Corrosion Inhibitors.** H. R. BAKER AND W. A. ZISMAN. Paper, A.S.L.E. 6th Ann. Conv., Philadelphia, Apr. 16-18, 1951. *Lubrication Eng.*, 7, 117-122 (1951) June.

Progress of post-war research on polar-type rust inhibitors is reported. New material is presented on the structure of soaps and amine-acid complexes, the colloid state of polar compounds in non-aqueous systems, the adsorption on metals, and the mechanism of corrosion inhibitors. Advances in rust-inhibition test methods, including work on vapor-type inhibitors, are reviewed. 40 references.—INCO.

### 5.8.4, 5.8.2

**Corrosion Inhibitor.** *Chem. Eng.*, 58, No. 3, 168, 170 (1951) Mar.

A liquid corrosion inhibitor for steam and condensate lines, designated as No. 160 Series Corrosion Inhibitor, is effective against carbon dioxide and oxygen in the system. The inhibitor acts in two ways: by neutralization and by surface adsorption. The amines of which it is composed, volatilize and pass from the boiler with the steam. Upon condensing, they neutralize the condensate, increase its pH, and thus minimize its corrosiveness on ferrous metals. Upon their return to the boiler with the condensate, they again volatilize with the steam and are available for recycling through the system. The second action is the result of adsorption on metal surfaces. In effect, it produces a protective film to polarize the cathodically active points

which may exist in the system. Manufactured by Allis-Chalmers Co.—INCO.

### 5.8.4

**Rust-Inhibitor.** *Petroleum Refiner*, 30, No. 6, 214 (1951) June.

A new oil-soluble rust inhibitor, L-1673, protects metals from corrosion 10-15 times longer than previous formulations. The main advantage of the new formula is that it is not easily removed because polar compounds contained in ALOX-L-1673 adhere tenaciously to metal surfaces, bonding the oil to the surface to form a dense barrier to corrosion by moisture, salt water and corrosive gases. Mfrd. by Alox Corp.—INCO.

## 8. INDUSTRIES

### 8.1 Group 1

#### 8.1.2, 5.3.4

**Galvanized Steel Windows Need No Paint—No Maintenance.** *Architectural Forum*, 93, 144 (1950) Sept.

Windows are galvanized before bonding, with the zinc coating extra thick to assure long life. Windows so treated have stood up without painting for 30 years or more.—MR.

#### 8.1.2, 5.4.5

**Protecting Structural Steel.** G. T. COLEGATE. *Iron and Coal Trades Rev.*, 141, 1035 (1950); 142, 37, 87, (1951); *Paint, Oil Chem. Rev.*, 114, No. 8, 46 (1951).

Methods employed in the preparation of steel-work prior to painting, the selection of the proper primer and testing methods are discussed.—RPI.

#### 8.1.4, 6.6.5, 7.2

**Corrosion and Corrosion Control: The Use of Asbestos Cement Pressure Pipe to Combat Soil Corrosion in Winnipeg.** W. D. HURST. *Water and Water Eng. (Br.)*, 55, 90 (1951) Mar.

Winnipeg, pop. 235,000, water supply is delivered to reservoir system by gravity from lake through concrete aqueduct 96 miles long. Water soft and noncorrosive. Daily consumption 19.5 mgd. (Imp.) soil lacustrine and alluvial silt overlying glacial till. Is rich in carbonate of lime. Principal salt deposits encountered in shallow excavations include objectionable sulphates of calcium, magnesium, and sodium. Soluble sodium, magnesium, and calcium salts among chief causes of high corrosiveness. Action on underground pipe where water dissolves soil salts. Solution then acts as electrolyte with metallic constituents of pipe walls and fittings. Electrolysis another major factor causing deterioration of pipe material in Winnipeg.

In 1913, construction commenced on 96-mi., concrete aqueduct of Greater Winnipeg Water Dist. In 1919, alk. ground water attacked external surface of aqueduct. No serious alkali disintegration of concrete made with Kalicrete, sulphate-resisting cement, experienced since first used in Winnipeg.

Shipley and Blackie concluded soil corrosion of water mains definitely established. Backfilling c-i. water mains with gravel and underdraining them would protect them in the same way as protected concrete. Difficult to find a coating for cast iron that would stand up to temp. differences. In this area (+100° to -35° F.).

Tests to demonstrate resistance of asbestos-cement pipe to soil corrosion

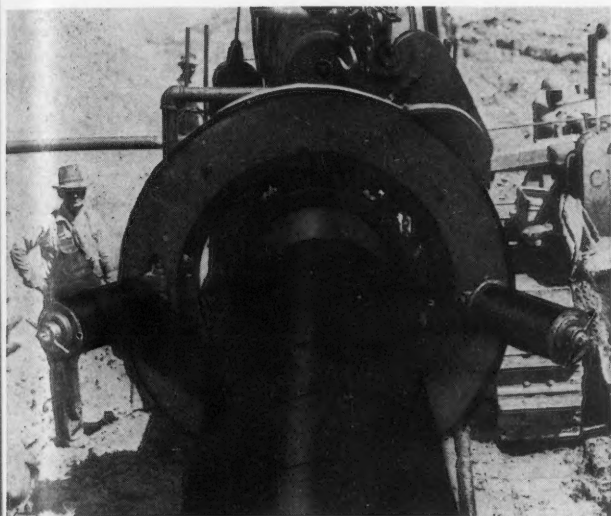
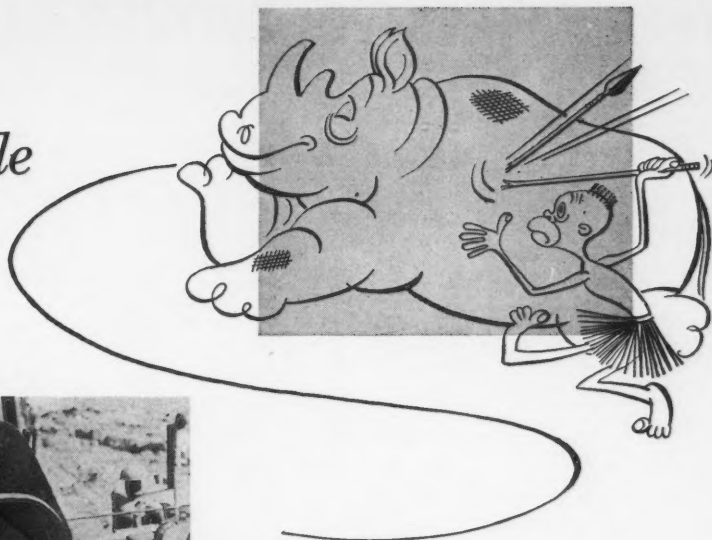
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were made in lab. for approx. 1 yr. with satisfactory results. In 1932, trial line consisting of 752 ft. of 18-in. and 431 ft. of 14-in. Class C. Transite pipe laid in street with particularly corrosive soil. Conditions aggravated by severe electrolysis from close proximity of electric substation. In 1937, trench opened and pipe carefully examined. No indication soil had deleterious effect on pipe. In Nov. 1946, extensive investigations undertaken, with following results: no flow capac. loss, no softening of pipe, pressure tests showed failure at 325 and 430 psi. int. pressure, no leakage from coupling and pipe when tested at 260 psi., pipe sustained 10,260-lb. max. ext. load before crushing, resisted 4,610-lb. force before breaking outward and freeing corporation cock, soundness of rubber rings was substantiated by pressure tests. Use of asbestos-cement pipe best answer so far for local corrosion problem. Cracking can be reduced by better laying and backfill methods together with other improvements still in study stage.

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Rhino's tough hide  
that protects  
what's inside...*



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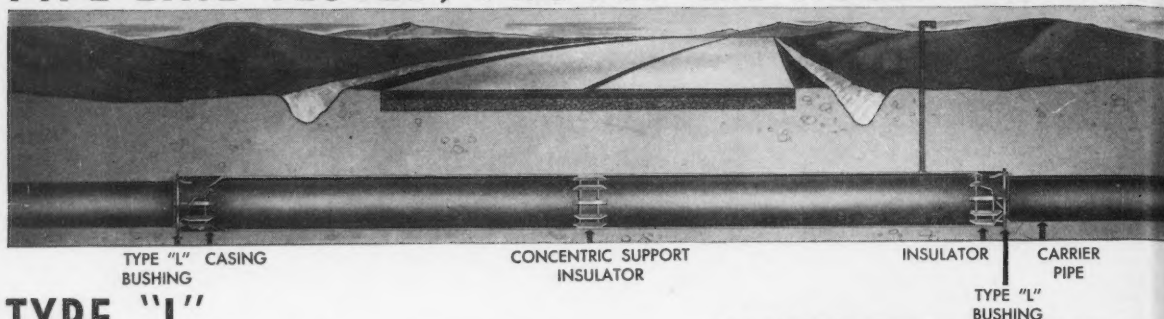
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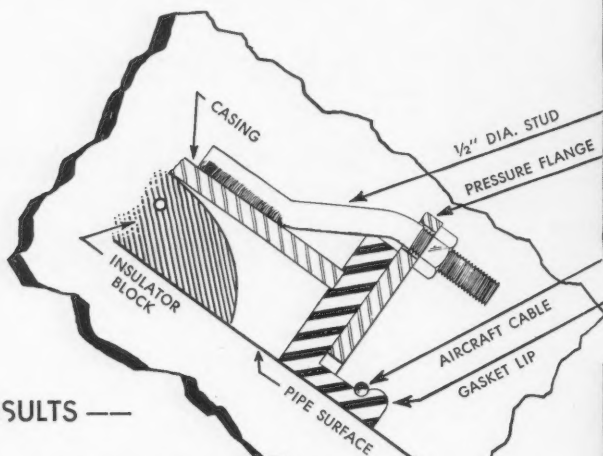
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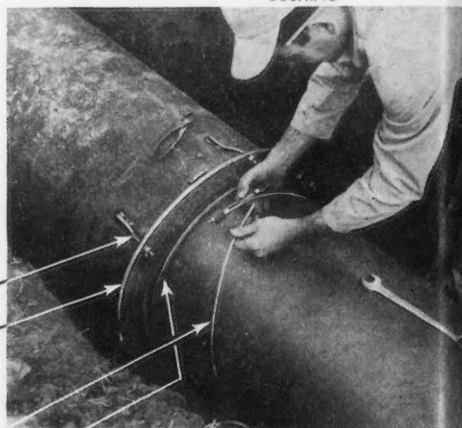
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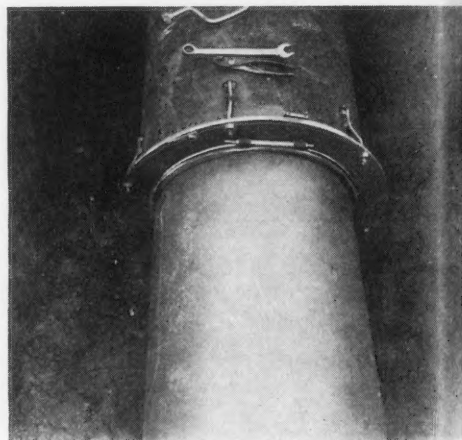


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  - TIGHT TO THE PIPE as aircraft cable (4,600# tensile) is tightened to gasket lip. Union is rubber covered to INSULATE galvanized cable assembly from bare casing structure.
3. Always Insulated from the pipe line when a Concentric-Support Insulator is installed just inside casing after the "drag section" is in place.



Assembling cable with rubber-covered union for clamping gasket lip to pipe.



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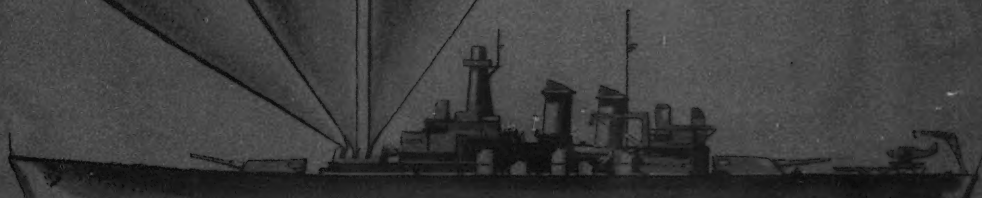
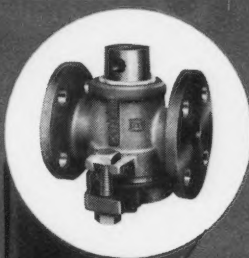
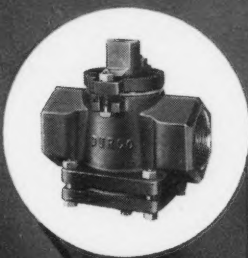
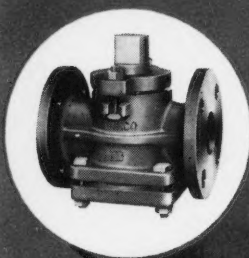


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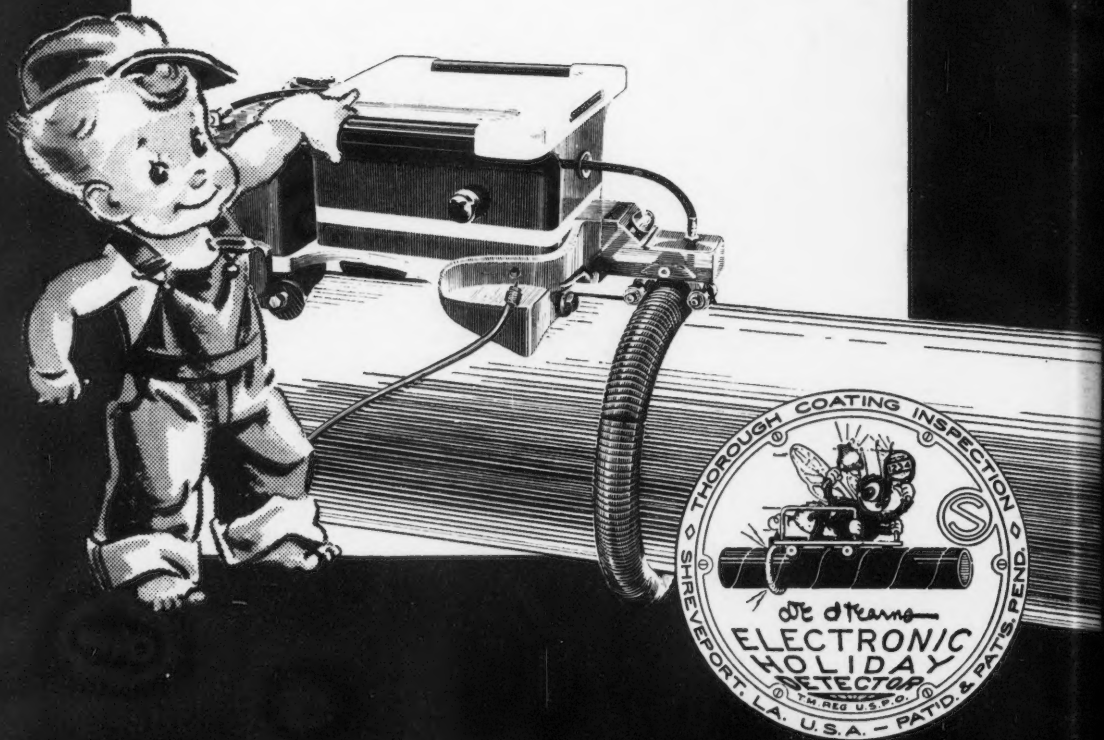
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